

*Dedicated to*



**Late Shri Mohan Lal Gupta**

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VOL. 1

# BIOLOGY

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## Chapter 1.1

# The Living World

## 1.1 Nature and Scope of Biology

**Science** : The term science is derived from Latin word *scientia* which means knowledge. So, the term 'science' is used for knowledge gained by actual observation, found correct on verification and put in a systematic manner or science provides us information based on facts. There are several branches of science, each dealing with a specific subject.

**Biology** : It is the combination of two Greek words *bios* and *logos*. *Bios* means life and *logos* means study. Thus, biology is the branch of science which deals with the study of life. The first major biological observations were made by ancient Greek naturalist Aristotle (384-322 B.C.). Aristotle has been designated as Father of biology. The term biology was given by French naturalist Lamarck and Gottfried Treviramus of Germany (1744-1829). Biology has been further classified into.

(1) Botany

(2) Zoology.

The science of plants is called Botany. The word botany has been derived from Greek word *botane* which means pasture or plants. Technically, botany is called Phytology (Gk. *phyto* = plants; *logos* = study). Theophrastus (370-287 B.C.) is known as Father of botany. Zoology is the study of animals (Gk. *zoon* = animals; *logos* = study). **Aristotle** is called Father of zoology. Being broad-based and with multi-disciplinary approach, the term biology has been replaced by Life Sciences or Biological Sciences.

**Microbiology** : It is the branch of biology which deals with different aspects of microorganisms. **Leeuwenhoek** (1632-1723) is called Father of microbiology.

### Some Branches of Biology

**Anatomy** : Study of internal structures of plants and animals after dissection.

**Biochemistry** : Study of chemistry of living matter (i.e., chemical composition, nature, mode of formation, functioning) in relation to life activities.

**Cytology** : Study of the structure and functions of cells and their organelles.

**Ecology** : Study of relationship between organisms and environment.

**Embryology** : Study of developmental stages of organisms upto hatching or birth.

**Endocrinology** : Study of endocrine glands and hormones action in animals.

**Evolution** : Study of the origin of life and the gradual differentiation or descent of species.

**Histology** : Study of tissues by microscopy.

**Immunology** : Study of resistance of organisms to infection.

**Limnobiology** : Study of fresh water lakes, ponds and streams.

**Morphology** : Study of form and structure of animals.

**Palaeozoology** : Study of fossil animals.

**Physiology** : Study of functions of various parts within the organisms.

**Radiobiology** : Study of effects of radioactivity on life.

**Taxonomy** : Study of classification of organisms and their evolutionary relationships with other organisms.

**Zoogeography** : Study of the distribution of animals over the earth.

**Zoopathology** : Study of diseases of animals.

### Specified Branches of Biology

**Acarology** : Study of mites and ticks.

**Agriculture** : Science of farming, raising crops and animal husbandary.

**Angiology** : Study of blood vascular system including veins and arteries.

**Anthology** : Study of flowers.

**Bacteriology** : Study of bacteria.

**Bryology** : Study of mosses and liverworts.

**Cardiology** : Study of heart.

**Dermatology** : Study of skin covering the body.

**Epidemiology** : Study of infection of parasites or epidemic diseases.

**Ethnology** : Study of different races of mankind.

**Etiology** : Study of cause of disease.

**Gerontology** : Study of growing old.

**Gynaecology** : Study of female reproductive organs.

**Haematology** : Study of blood.

**Hepatology** : Study of liver.

**Kalology** : Study of human beauty.

**Leprology** : Study of leprosy.

**Molecular biology** : Study of life sciences on molecular level (e.g, nucleic acids i.e., RNA & DNA and proteins).

**Myrmecology** : Study of ants and anteaters.

**Nematology** : Study of nematodes.

**Nephrology** : Study of kidney.

**Neurology** : Study of nervous system including brain.

**Oncology** : Study of tumours.

**Oology** : Study of eggs of birds.

**Ornithology** : Study of birds.

**Osteology** : Study of bones.

**Palaeontology** : Study of fossils and their distribution.

**Pomology** : Study of fruit.

**Rhinology** : Study of nose and olfactory organs.

**Serology** : Study of serum, Study of antigen-antibody reactions.

**Serpentology** : Study of snakes.

**Termitology** : Study of termites.

**Toxicology** : Study of toxic effects of drugs and harmful compounds.

**Therapeutics** : Science of healing.

**Trophology** : Study of nutrition.

**Virology** : Study of viruses.

**Zoophytology** : Study of drifting organisms such as diatoms.

**Zymology** : Study of fermentation processes.

### Fathers of Various Sciences

Father of Zoology and Biology and Founder of Embryology : *Aristotle*

Father of Botany : *Theophrastus*

Father of Genetics : *G.J. Mendel*

Father of Evolutionary ideas : *Empedocles*

Father of Eugenics : *Francis Galton*

Father of Mutation : *Hugo de Vries*

Father of Modern Embryology : *Karl Ernst Von Baer*

Father of Palaeontology : *Leonardo da vinci*

Father of Taxonomy : *Carolus Linnaeus*

Father of Special Creation Theory : *Father Saurez*

Father of Blood groups : *K.Landsteiner*

Father of Blood circulation : *William Harvey*

Father of Comparative Anatomy : *G. Cuvier*

Father of Modern Genetics : *W.Bateson*

Father of human genetics : *Archibald Garrod*

Father of Medicine : *Hippocrates*

Father of Microbiology : *Leeuwen hoek*

Father of Immunology : *Edward Jenner*

### Biology in Ancient India

About 740 plants and 250 animals have been mentioned in Vedic literature. Few significant references in old literature are,

(1) **Chandyogya Upanishad** : Here the animals have been classified into three categories –

(i) **Jivaja** (Viviparous) e.g. mammals.

(ii) **Andaja** (Oviparous) e.g. birds, reptiles, insects and worms.

(iii) **Udbhija** (Vegetal origin) e.g. small animals.

(2) **Susruta Samhita** (600 B.C.) : Here organisms were classified into,

(i) **Sthavara** in which immobile organisms like plants were kept.

(ii) **Jangama** in which mobile organisms like animals were placed.

### Medical Science in Ancient India

Two Ashwini Kumars has been said to be practising medicine during Vedic times. Dhanvantari has been called as 'God of medicine'. Susruta has been called as 'Father of surgery'. Few important references are

(1) Susruta studied human anatomy on dead bodies.

(2) Susruta carried plastic surgery on human nose (rhinoplasty).

(3) **Ophthalmic surgery** : Susruta carried an eye surgery like extraction of cataracts.

(4) **Clotting of blood** : Susruta used non-poisonous live leeches for checking clotting of blood in post operative conditions. Now its clearly established that hirudin is released along saliva of leeches to produce this kind of effect.

(5) **Charaka Samhita** (100 B.C.) : It is said to be primarily written by Agnivesa under the guidance of Atreya (600 B.C.). Charaka was first to discuss the concepts of digestion, Metabolism and immunity.

## Scope of Biology

Biology creates an awareness of vast array of forms of life which normally goes unseen. Biology offers a large scope and provides a large field for study.

(1) **Helps us to understand ourselves better** : It unfolds different queries of life alongwith its cultural, social, philosophical and economical aspects. So it helps in understanding the life better.

(2) **Biology and inter-relationship of living beings** : Study of biology helps us in understanding the wonderful phenomenon and laws of nature which finally tell us to predict the behaviour of different living beings under changed conditions.

(3) **Biology and resources** : Biology helps us to know how to trap and conserve the resources available to us e.g. fishes, birds, forests etc.

(4) **Biology and literature** : Knowledge of Natural Biology has greatly enriched the literature with their references in stories and poems etc. Poets and other authors have been inspired by the beautiful and interesting plants and animals and frequently figure them in stories, poems and dramas.

(5) **Study of nature is a rewarding experience** : Many plants like *Narcissus*, *Dahlia*, *Gloriosa*, *Roses*, *Marigold*, *Aster*, etc. are used for ornamental purposes. The variety available in animals is widely enjoyed in zoological parks.

(6) **Solving problems** : Biology makes us to understand the present day problems such as population growth, pollution, conservation of wildlife and survival of man etc. The future directions of biotechnology, conservation of biodiversity, maintenance of environment and human welfare remain in the hands of biologists.

(7) **Biology-Medicinal aspect** : Several plants like *Atropa belladonna*, *Cinchona* are sources of atropine, quinine etc. Many members of fungi such as *Penicillium* and *Streptomyces* give rise to antibiotics like penicillin and streptomycin. Plants are the major source of vitamins. Drugs are first tested on animals before being used for treating man. Animals provide scientific hints for the production and use of medicines. Many diseases like malaria are caused and transmitted by animals.

(8) **Solving approach of biology** : Knowledge for eradication of diseases like malaria, small pox, etc. have been achieved by scientists basically due to desire and determination to solve the problem.

(9) **Ecosystem and living organisms** : Biology helps us in understanding the various ecosystems. The living community and non-living environment interact with each other and exchange of material in them takes place.

(10) **Biotechnology** : Biotechnologists have produced many genetically modified (GM) crops. Plenty of studies are being made by geneticists, evolutionists and cytologists to fudge the efficacy of biotechnology.

## 1.2 Understanding Life

### Basic Properties of Living Organisms

Living beings are called organisms. Living organisms are similar to non-living objects in being – formed of similar elements which combine in similar way to form similar molecules (called biomolecules in living organisms) and follow similar physical and chemical laws like gravitation, magnetism, action and reaction etc. living organisms show a great biodiversity and are classified into different kingdoms-Monera, Protista, Fungi, Plantae and Animalia. But all of these share the following properties –

- (1) They have definite organisation.
- (2) They always have cellular nature so are either unicellular (e.g. *Amoeba*, *Paramecium* etc.) or multicellular (e.g., *Hydra*, man etc.).
- (3) They show co-ordination between different parts of body to maintain homeostasis (constant internal environment) inside the body.
- (4) They have the ability of movements and locomotion.
- (5) They show metabolic functions in the presence of energy.
- (6) These have the ability of intussusceptional (internal) growth and development.
- (7) These have specific receptors (e.g., sense organs to receive external and internal stimuli) and specific effectors (e.g., muscles and glands to give specific response).
- (8) These have regulatory mechanisms (e.g., nerves and hormonal in animals, and only hormonal in plants) to maintain homeostasis inside the body.
- (9) These show adaptations to their environment to increase their chances of survival.

(10) These show variations which help in speciation and evolution.

(11) These have reproductive powers for continuity of their race.

### Levels of Biological Organization

(1) **Levels of Organization common in both living and non-living**

(i) **Atomic level** : The lowest level of organization in both living and non-living is the atom. All living organisms are basically made up of four chemical elements carbon (C), hydrogen (H), oxygen (O) and nitrogen (N) with only about 1% other elements. The non-living matter may possess other elements (such as silica, calcium, iron, etc.) in variable composition.

(ii) **Molecular level** : Atoms combine to form molecules, which undergo chemical reactions to form organelles.

Atoms → Molecules → Inorganic compounds → Simple organic compounds → Complex organic compound → Protoplasm → Cell.

(2) **Levels of Organization found only in living organisms**

(i) **Cellular level** : All multicellular organisms are made up of cells. The cell is considered as basic unit of life and constitutes the smallest level of organisation of the living organisms.

(ii) **Tissue level** : In multicellular organisms similar or dissimilar cells, having a common origin and a common function, combine to form a tissue. Each tissue performs a specific role (e.g., xylem conducts water and minerals in plants).

(iii) **Organ level** : Different tissue are organised to form distinct organs. For example, xylem, phloem chlorenchyma, parenchyma get organised to form a leaf.

(iv) **Organs System level** : A group of organs that coordinates to performs a major function forms the organs system. For example, the brain works with the spinal cord and a network of nerves to form the nervous system.

(v) **Individual or Organismic level** : A multicellular individual, having many organ systems, forms an organismic level of organisation.

Cell → Tissue → Organ → Organ system → Individual.

(3) **Levels of organization beyond the individual organism**

(i) **Population level** : All the individuals of a species in a particular area, where they interact with each other, belong to a population. For example, there is a population of Oak trees in a temperate deciduous forest.

(ii) **Community level** : The populations of different species of plants and animals present in a particular area make up biotic community.

(iii) **Ecosystem level** : Populations of different plants and animals interact among themselves and with the non-living components of the area form as ecosystem.

(iv) **Biosphere level** : The different ecosystems (small or big) of all the geographical regions of the world form the biosphere or the entire livable part of the earth.

### Building blocks of life and their function

Living organism is formed of many types of inorganic as well as organic biomolecules. Inorganic compounds include water, minerals etc. and are always micro-biomolecules (small sized, low molecular weight, readily soluble in water and diffusible) while organic molecules may be micro (e.g. monosugars, amino acids etc.) or macro-biomolecules (large sized, high molecular weight, insoluble or slightly soluble and non-diffusible e.g., proteins, fats, nucleic acids, etc.). These both types of biomolecules play important roles in metabolism :

(1) **Role of Water** : Water forms 70-90% of the cellular pool. It forms 65% (about two-thirds) of human body. It is formed of H and O in the ratio of 2:1. 95% of water is found in free state and 5% in combined form in the cell. Water helps in sustaining the life processes. So water is called elixir or cradle of life as life is not possible in the absence of water.

(2) **Role of Oxygen** : Oxygen is mainly utilized in aerobic cell respiration of the nutrients inside the mitochondria to produce energy-rich ATP molecules so is essential for life. In the absence of oxygen, only 5% of energy available is released.

(3) **Role of Sodium chloride (common salt- $\text{NaCl}$ )** : Sodium chloride plays important roles in metabolic functions of body especially when in ionic form.

(4) **Role of Carbohydrates** : Carbohydrates are organic compounds formed of C, H and O generally in the ratio of 1:2:1. These are commonly called saccharides (Gk. *saccharon* = sugar). Carbohydrates are the main storage molecules and most organisms use carbohydrates as an important fuel, breaking these bonds and releasing energy to sustain life.

(5) **Role of Proteins** : Proteins are polymeric compounds formed by interlinking of amino acids (monomers) by peptide

bonds. Out of about 100 types of amino acids, only 20 types of amino acids are of biological importance, so are called Magic-20. Proteins play a vital role in the formation of structures in living organisms. Like carbohydrate and fat, protein can be broken down with the release of energy. Protein is not stored as such in the body and it is normally only used as a substantial source of energy in conditions of starvation.

(6) **Role of lipids** : Lipids comprise a major group of insoluble hydrocarbons having many functions. These are polymers of alcohols (e.g. glycerol) and fatty acids interlinked by ester bonds.

(7) **Role of Nucleic Acid** : These are polymers of nucleotides interlinked by phosphodiester bonds, so called polynucleotides. Each nucleotide is formed of 3 components : a pentose sugar (e.g. ribose in RNA and deoxyribose in DNA), a phosphate group and an inorganic nitrogen-base (a purine or a pyrimidine).

### Matter and Energy

Technically speaking, matter and energy are interchangeable as expressed by Albert Einstein's famous equation  $E = mc^2$ ; energy equals mass times the square of the speed of light ( $c^2$ ).

For the chemical reactions that occur within living organisms, however, we can treat matter and energy as quite distinct from one another. Matter is the physical material of the universe; energy is the capacity to do work.

**Close and Open system** : A system is a portion of the universe that is selected within a definite boundary. The part other than the system is called surrounding.

As system is said to be closed if it can exchange energy but not matter, and in this energy can be gained or lost (through stainless walls) but not matter. A system said to be open if it can exchange matter and energy with surroundings. All living systems are open systems because they are continuously exchanging matter and energy with their surroundings.

### Kinetic and Potential energy

Kinetic energy is the energy of movement and this include not only movement of large objects but also movements such as electrical energy (movement of electrons) and heat (movement of atoms and molecules).

Potential energy is stored energy that can be released as kinetic energy under right conditions.

The food which you eat has chemical potential energy, some of which is converted into kinetic energy.

### Laws of Thermodynamics

The laws of thermodynamics describe the basic properties of energy. All interactions among pieces of matter are governed by the two laws of thermodynamics. The laws of thermodynamics deal with "isolated systems" which are any parts of the universe that cannot exchange either matter or energy with any other parts.

**First Law of Thermodynamics** : The first law of thermodynamics states that energy can neither be created nor destroyed; but energy can change from one form to another.

In other words, within an isolated system the total quantity of energy remains constant. The first law is therefore often called the law of conservation of energy.



**Second law of Thermodynamics :** The second law of thermodynamics states that the amount of useful energy always decreases when energy is converted from one form to another.

In other words, every transfer or transformation of energy makes the universe disordered; no physical process or chemical reaction is 100 per cent efficient.

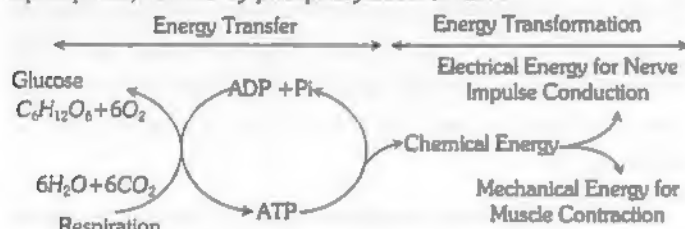
Entropy is a measure of the disorder or randomness within a system.

### Energy flow

(1) **Energy Transformation :** It is the phenomenon in which one form of energy is changed into another form of energy, e.g. in photosynthesis (anabolism), radiant (Kinetic) energy of sunlight is changed into chemical (potential) energy of glucose. All the living organisms depend upon this transformation.

(2) **Energy Transfer :** It involves the movement of energy from one source or area or substance to another in the same form. e.g. in cell respiration (catabolism), oxidative break down of glucose occurs inside the mitochondria of aerobic plants and animals.

The glucose is enzymatically catabolised by stepped breakdown into water and  $\text{CO}_2$  and about 686 kcal of energy is released per mole of glucose. A part of released energy is stored as chemical energy in high energy bonds of ATP (adenosine triphosphate) formed by phosphorylation of ADP.



**Table : 1.1-1 Some examples of Energy transformation.**

Type of Energy Transformation	Example
Chemical to electrical	Nerve cell
Light to electrical	Retina of eye
Chemical to osmotic	Kidney
Chemical to mechanical	Muscles and cilia
Sound to electrical	Ear
Chemical to light	Bioluminescence
Chemical to heat	Homeothermy

### Homeostasis

Homeostasis (Gk, *homoios* = same; *stasis* = standing) is the maintenance of a constant internal environment or steady state (blood plasma, haemolymph, extracellular fluid, etc.). The French physiologist Claude Bernard (1857) realized the importance of stability in the internal environment (*milieu interieur*). The term 'homeostasis' was first coined by the American physiologist Walter Bradford Cannon in 1929. Homeostasis is a fundamental property of life and is considered a good sign of life.

### Thermoregulation

Regulation of body heat in response to the internal and external environment of the body is called thermoregulation.

As far as temperature regulation is concerned, animals can be divided into two groups: poikilothermous and homeothermous.

Poikilothermic means 'having a variable temperature'. Poikilothermic animals are described as 'cold-blooded', their body temperature changing with fluctuation in the environmental temperature. Homeothermic means 'having the same temperature'. Homeothermic animals (mammals, birds and a few fishes like tuna fish and sword fish) are popularly described as 'warm-blooded'; their body temperature is independent of environmental temperature.

### Growth

Growth is one of the most important characteristics of living organisms. Growth is defined as a permanent increase in size or weight or volume of an organism or its body parts e.g. kittens grow into cats, puppies grow into dogs and a human baby grows to become adult.

At the molecular level, the growth involves,

(1) Increase in the size of cells due to synthesis of protoplasmic substances like cytoplasm and nucleus.

(2) Addition of non-living aprotoplasmic materials like intercellular matrix, fibres of connective tissue, etc. These are secreted by the cells.

(3) Increase in the number of cells by cell division. It occurs through cell cycle which is formed of interphase and M-phase.

(4) Growth is the result of greater anabolic (synthetic) processes over the catabolic (destructive) processes in an organism.

The process in which reserve food material is utilized and exhibited negative growth is called degrowth.

### Development

(1) In general, growth involves three processes or strategies namely cell proliferation, cell enlargement and secretion of large amount of extra cellular matrix.

(2) Growth is an important part of development, continuing throughout life.

(3) Early embryonic developmental stages constitute prefunctional state of life.

(4) The biological process of growth and differentiation enables the animal to enter the functional state of life.

(5) Morphogenesis refers to generation of form and structure during development of an individual organism.

(6) Morphogenesis produces new forms by involving cell movements.

(7) Morphogenetic movements of large number of cells during development is particularly noticed during gastrulation.

(8) Differentiation results in increasing diversity of cells.

### Reproduction

(1) Reproduction is one of the most important life functions.

(2) Reproduction is the only way that living things can perpetuate themselves.

(3) There are a number of different ways that various kinds of organisms reproduce and compensate for the loss of life due to death.

(4) Some reproductive processes known as sexual reproduction involve two organisms and their sex cells.

(5) Asexual reproduction occurs when organisms make identical copies of themselves.

## Adaptation

(1) Adaptation may be defined as any characteristic of an organism which makes the organism better suited to its environment.

(2) In other words, an adaptation improves the performance and survival of the organism in its the environment.

(3) Individuals with favourable characteristics replace those with less favourable characteristics.

(4) Adaptation improves the match between organisms and their environment.

(5) On the basis of their nature and role in evolution the adaptation are classified into short range or temporary and long range or permanent adaptation.

## Life Span

The average longevity of an organisms from birth to death is called life span. It is different in different living organisms.

## Death

Death is the permanent breakdown and finally stopping of vital functions of body, especially heart beat and respiration.

### Characteristics

(1) It is the last event in the degenerative processes of ageing.

(2) Death involves widespread cell breakdown and cell death.

(3) Death of an organism involves the death of body cells. But all the body cells do not die at same rate e.g. ciliated cells lining the respiratory tract of mammals continue to beat their cilia for long time even after clinical death.

(4) There is no natural death in some protists e.g. *Amoeba* and monerans like bacteria, etc.

## Taxonomy

The art of identifying distinctions among organisms and placing them into groups that reflect their most significant features and relationship is called biological classification. Scientists who study and contribute to the classification of organisms are known as systematists or taxonomists, and their subject is called systematics (Gk. *Systema* = systems or order or sequence) or taxonomy (Gk. *Taxis* = arrangement; *nomos* = law).

**Classical taxonomy** : Taxonomy based on all available information and attempting to classify organisms, according to their origin, evolution and variations is called classical taxonomy. A taxonomist engaged in studying origin, evolution, variations and classification of organisms is called classical taxonomist.

## History of classification

References of classification of organisms are available in **Upanishads** and **Vedas**. Our Vedic literature recorded about 740 plants and 250 animals. Few other significant contributions in the field of classification are :

**Chandiyogya upanishad** : In this, animals are classified into three categories-viviparous *Jivaja*, oviparous *Andaja* and minute *Udbhija*.

**Susruta samhita** : It classified all 'substances' into **sthavara** (immobile) e.g., plants and **jangama** (mobile) e.g., animals.

**Parasara** : Here, angiosperms were classified into **dvimatruka** (dicotyledons) and **ekamatruka** (monocotyledons).

He was even able to find that dicotyledons bear **jalika parana** (reticulate veined leaves) and monocotyledons bear **maun lapama** (parallel veined leaves).

**Hippocrates and Aristotle** : They classified animals into four major groups like insects, birds, fishes and whales in his *Scala naturae*.

## Nomenclature

Nomenclature is the assignment of a distinctive name to each species. Almost all plants (and animals too) are known by different common names in different parts of the world. Even within the same country people of different states and regions use different common names.

*Ipomoea batatas*, for example, is called **sweet potato** in English, **Shakarkandi** in Hindi, **Meetha alu** in Assamese and Bengali, **Kundmul** in Telugu, **Ratalu** in Marathi and **Jenasu** in Kannad. Similarly, the common house sparrow is called "Goraiya" in India, "Sparrow" in England and "Haussperling" in America. The common names are thus quite confusing.

The earliest scientific names were **polynomial**, i.e., they were composed of many words (which gave the characteristics of plants), e.g., *Sida acuta* (a member of Malvaceae) was named as *Chrysophyllum folis, ovalis superne glabris parallel striatis subtus, tomentosonitidis* such long names were difficult to remember. Hence, to make it easier binomial system of nomenclature was introduced.

**Binomial system of nomenclature** : The credit of giving binomial system of nomenclature goes to Swedish naturalist, **Carolus Linnaeus**. He employed this system in his book *Species Plantarum*, published in 1753. According to this system the name of a plant or animal is composed of two Latin (or Latinised) words, e.g., potato is *Solanum tuberosum* and house sparrow is *Passer domesticus*. The first word (i.e., *Solanum*) indicates the **name of the genus** (called **generic name**) and the second word (i.e., *tuberosum*) denotes the **name of the species (or a specific epithet)**. The generic name always begins with a capital letter and the specific name with a small letter and printed in italics.

The generic and specific names always have some meaning. They are based on some special characters of the plant and animals, on the name of any scientist or on some legend.

Usually the name of the author, who names a organism, is also written in full or in abbreviated form after the specific name. Thus, in case of *Mangifera indica* L., the L. stands for **Linnaeus** and in *Lychnis alba* Mill., the Mill. stands for **Miller**.

Sometimes a single species is described under different names by different authors. These names are called **synonyms**. In such cases, the name under which the species is first described, is considered to be valid.

**Trinomial nomenclature :** Certain species are divisible into smaller units, called subspecies or varieties, on the basis of finer differences. The name of the variety is written after the specific name. Thus, the name may become trinomial or three word name. e.g., *Homo sapiens europaeus* is the name of the man of European race. Trinomial nomenclature is simply an extension of the Linnaean system.

**Code of biological nomenclature :** Anyone can study, describe, identify and give a name to an organism provided certain universal rules are followed. These rules are framed and standardised by International Code of Botanical Nomenclature (ICBN) and International Code of Zoological Nomenclature (ICZN). The codes help in avoiding errors, duplication, confusion and ambiguity in scientific names. The codes are established and improved upon at International Botanical and Zoological Congress held from time to time. The names of bacteria and viruses are decided by International Code of Bacteriological Nomenclature (ICBN) and International Code of Viral Nomenclature (ICVN). Similarly, there is a separate International Code of Nomenclature for Cultivated Plants (ICNCP).

### Valid name

- (1) It is not a tautonym (e.g., same generic and same specific name).
- (2) The name is new and given according to binomial nomenclature with abbreviation of author's name.
- (3) Its type specimen has been described in latin.
- (4) The type specimen is kept in a recognised herbarium/collection.
- (5) The new name has been published in a widely circulated scientific journal.
- (6) All the names previously given to the organism must be indicated.
- (7) If the new name is higher than species, the taxonomic category is indicated.

### Type of specification

**Holotype :** The original type specimen from which the description of a new species is established.

**Isotype :** Duplicate of holotype, as another branch of the same tree.

**Lectotype :** Specimen selected from original material to serve as nomenclatural type where there is no holotype.

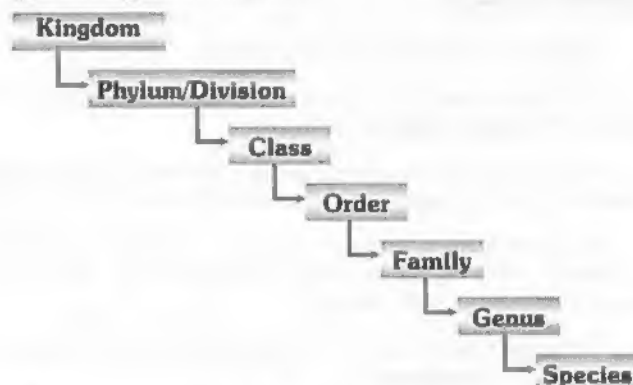
**Neotype :** New nomenclatural type when the original type is missing.

**Paratype :** Any other specimen described along with holotype.

**Syntype :** Any of two or more specimens cited by an author when there is no holotype.

### The taxonomic hierarchy

It is the sequence of arrangement of taxonomic categories in a descending order during the classification of an organism. Hierarchy was first given by Linnaeus who used only five categories – class, order, genus, species and variety. The last one was discarded and three added so that now there are seven **obligate categories**. They are :



Some categories have been added to this list. They are called **intermediate categories**, e.g., Subkingdom, superphylum or superdivision, subdivision, superclass, subclass, superorder, suborder, superfamily, subfamily, tribe, subspecies, variety etc.

**Taxon :** Term taxon was introduced by ICBN during 1956 and defined by Mayr (1964). The term taxon is used to represent any unit of classification. The unit (i.e., taxon) may be large (e.g., Plant Kingdom) or small (e.g., Algae, Fungi, or a single species).

**Category :** Various sub-divisions of plant kingdom such as division, class, order, family, etc., are referred to as categories. In the hierarchy of categories, kingdom is the highest and species is the lowest category. The following is hierarchical series :

(1) **Kingdom :** It is the highest category in biological classification. e.g., all plants are included in plant kingdom.

(2) **Division (Eichler or phylum) :** It is a major group in the Linnaean hierarchy used in the classification of plants (equivalent to phylum in animal classification). It is a taxonomic category between kingdom and class. The subcategory of division is **subdivision**. The suffix of division is – phyta.

(3) **Class (Linnaeus, 1735) :** A division is divided into classes. It is a taxonomic category between the division and order. Its suffix is – ae. The subcategories of class are subclass and series. The class contains organism least similar to one another.

(4) **Order (Linnaeus, 1735) :** A class includes one or more orders. It is a taxonomic category between the class and family. Its suffix is – ales. The subcategory of order is **suborder**.

(5) **Family :** An order is divided into one or more families. It is the taxonomic category between the order and the genus. Its suffix is – aceae. The subcategories of family are **subfamily (Suffix-oidae), tribe and subtribe**.

(6) **Genus :** The plural of genus is genera. It comprises a group of related species which has more characters in common in comparison to species of other genera. The subcategories of genus are **subgenus, section and subsection**.



(7) **Species (John Ray, 1693)** : It is the smallest rank and basic unit of taxonomic classification. The first letter of the species is denoted with small letter. The species is printed in *Italics* (It is underlined if hand written). A genus may include one or more species. The subcategories of species are **subspecies** or **varieties**, **subvarieties**, **form** and **subform**.

### Species concept

- (1) Species is the basic unit of taxonomy.
- (2) Modern concept of species is biological species concept introduced by **Ernst Mayr** (1942).
- (3) Mayr defined species as groups of interbreeding natural populations that are reproductively isolated from each other group.
- (4) The traditional concept of species was given by Linnaeus in *Systema naturae*; this is based on morphology and is also known as 'Morphological concept'.
- (5) Species inhabiting the same geographical area (identical or overlapping) are **sympatric**.
- (6) Species inhabiting different geographical areas are **allopatric**.
- (7) Related species which are reproductively isolated but morphologically similar are called **sibling species**.
- (8) Classical systematic is based on the 'Typological concept' by **Plato** and **Aristotle**.
- (9) Genetic species concept was given by **Lotsy** (1918), according to which, a species is a group of genetically identical individuals.
- (10) Species that contain two or more subspecies are called **polytypic species**.
- (11) Species that are not sub-divided into subspecies are called **monotypic species**.
- (12) Normally breeding is possible only within a species.
- (13) Two different species are reproductively isolated.

### System of Biological Classification

Different systems of classification proposed from time to time have been divided into three basic categories viz., artificial systems, natural systems and phylogenetic system (However, Redford, (1986), included mechanical systems as a fourth category).

(1) **Artificial system of classifications** : These systems are more or less arbitrary as the plants are classified merely on the basis of gross morphology, habit and their importance to man. The main advocates of artificial system of classifications were :

**Aristotle** : He also classified animals on the basis of habitat into water, land and air.

**Theophrastus (370 B.C. to 285 B.C.)** : Theophrastus was a disciple of Plato and later Aristotle. In his book *De Historia plantarum*, he classified about 500 kinds of plants into four major group; trees, shrubs, subshrubs and herbs.

**John Ray** : He was a British botanist who published three volumes of his work *Historia Generalish Plantarum* consisting of improved classification originally proposed by him in *Methodus Plantarum Noven*. He was the first to divide the groups herbs,

shrubs and trees into Dicots and Monocots on the basis of the presence of two or one cotyledons respectively. He coined the term **species**.

**Carolus Linnaeus** : Father of taxonomy. A Swedish botanist, who published an artificial system of classification based exclusively on floral characters. Linnaeus published several manuscripts including *Hortus cliffortianus* and *Genera plantarum* (1737). In his *Genera plantarum* he listed all the plant genera known to him. He published his best known *Species plantarum* in 1753. In this book he listed and described all species of plants known to him. He established binomial nomenclature.

(2) **Natural system of classifications** : These systems of classification are based not only on the characters of reproductive organs and structural morphology but used as many taxonomic characters or traits as possible to classify the organisms. The advocates of **natural** systems of classification are listed below :

**Carolus Linnaeus** : The first natural system of animal classification was developed by Linnaeus in his book "*Systema Naturae*" (10<sup>th</sup> edition 1758). Improvements were subsequently made by Haeckel (1864) and Lankester (1874).

**George Bentham (1800-1884) and Joseph Dalton Hooker (1817-1911)** : These two English botanists classified plants based on original studies of specimens. They published their well known scheme of classification in *Genera plantarum* (1862-83). This system of classification is still regarded as the best classification, especially from the practical point of view.

(3) **Phylogenetic system of classifications** : These systems of classifications are mainly the rearrangements of natural systems using as many taxonomic characters as possible in addition to the phylogenetic (evolutionary) informations. Some important phylogenetic systems of classifications were proposed by :

**A.W. Eichler (1839-1887)** : A German botanist who proposed phylogenetic system of classification and published in the third edition of *Syllabus der vorlesungen* (1883).

**Adolph Engler (1844-1930) and Karl Prantl (1849-1893)** : These two German botanists classified plant kingdom on the basis of their evolutionary sequences. They started with simplest flowering plants and ended with plants of complex floral structures.

**C.E. Bessey (1845-1915)** : He classified flowering plants on the basis of their evolutionary relationships.

**John Hutchinson (1884-1972)** : A British botanist published his phylogenetic system of classification in '*The Families of Flowering Plants*'.

**Armen Takhtajan (1980)** : A Russian botanist who published his system of classification in *Botanical Review*.

**Arthur Cronquist (1981)** : Published his classification in '*An Integrated System of Classification of Flowering Plants*'.

Phylogenetic systems of classification for animals given by Dobzhansky and Mayr.

### New Systematics or Biosystematics

The term new systematics was proposed by Sir Julian Huxley in 1940. In the new systematics, the species are considered related to one another, mutable and the work of gradual modification. This is in conformity with the facts of evolution.

**Forms of new systematics :** There are several forms of new systematics :

(1) **Morphotaxonomy :** It is based on the structural features of the organisms.

(2) **Cytotaxonomy :** It is based on cytological information of cell, chromosome number, structure and behaviour of chromosome during meiosis. **Karyotaxonomy** is a branch of cytotaxonomy which is based on banding pattern of chromosome.

(3) **Biochemical taxonomy or Chemotaxonomy :** It is based on the protein and serum analysis and on the chemical constituents of the organisms

(4) **Numerical taxonomy :** It involves quantitative assessment of similarities and differences in order to make objective assessments. Characters of organisms are given equal weight and the relationships of the organisms are numerically determined, usually with the aid of a computer.

(5) **Experimental taxonomy :** It is based on the genetic relationship determined with the help of experiments.

### Modern trends in systematics

**Two kingdom system of classification :** This system of classification is the oldest it was suggested by *Carolus Linnaeus* in 1758. He divided the living world (organism) into two kingdoms, *Plantae* (for all plants like tree, shrubs, climbers, creepers, moss and floating green algae) and *Animalia* (for animals).

**Three kingdom system of classification :** *Ernst Haeckel*, a German biologist and philosopher, suggested a third kingdom *protista* in 1866 for

(1) Unicellular organisms such as bacteria, protozoans and acellular algae.

(2) Multicellular organisms without tissue such as algae and fungi.

**Four kingdom system of classification :** It was proposed by *Copeland* in 1956. The two additional kingdoms were *Monera* for the bacteria and blue green algae and *Protista* for protozoans, algae and fungi.

**Five kingdom system of classification :** *R.H. Whittaker*, an American taxonomist. He proposed five kingdom system of classification in 1969.

This system replaced the old, two-kingdom grouping of living organisms. As already discussed, a division of living world merely into plant and animal kingdoms is too simple. It does not take into account the **gradual** evolution of distinct plant and animal groups and it allows no place for those primitive organisms that even now are neither plants nor animals nor that are both. In this classification eukaryotes were assigned to only four of the five kingdom.

Five-kingdom classification is based on the following five criteria :

- (1) Complexity of cell structure.
- (2) Complexity of organism's body.
- (3) Mode of obtaining nutrition.
- (4) Phylogenetic relationship.
- (5) Ecological life style.

**The five kingdoms are :** *Monera*, *Protista*, *Fungi*, *Plantae* and *Animalia*.

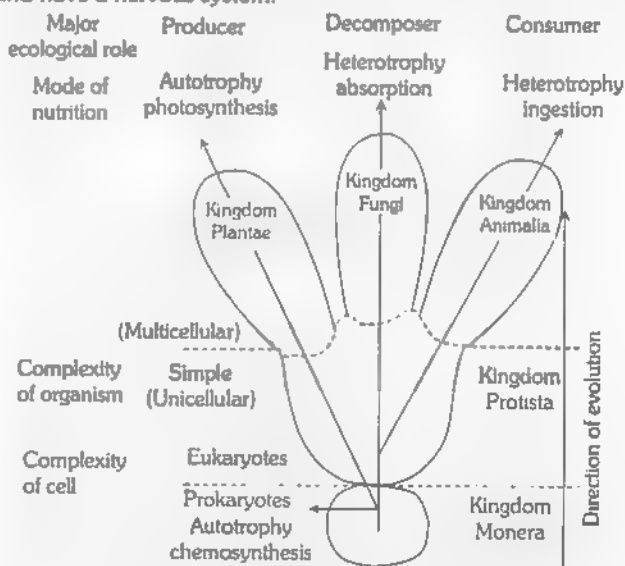
**Monera :** It includes all prokaryotic organisms, which may have autotrophic or heterotrophic type of nutrition and are surrounded by a rigid cell wall. They are usually unicellular ranging from one to a few micron size. They are important decomposers and mineralizers. It include *Bacteria*, *Actinomyces*, *Cyanobacteria*, etc.

**Protista :** They are mostly aquatic unicellular organisms, having eukaryotic organization. They generally have cilia or flagella and have diversified mode of life. Most of them are photosynthetic autotroph but some are holozoic, parasitic or even symbiotic. e.g., *Euglena*.

**Fungi :** They are diversified eukaryotic, heterotrophic organisms, body of which is made up of filamentous mycelium. They generally grow as saprophytes or parasites. They include moulds, mushrooms, puff balls etc.

**Plantae :** It includes all multicellular photosynthetic plants, which may have red, brown or green pigmentations except a few parasitic, saprophytic and insectivorous types. Most of the members are primary producers of land and water (*Phaeophyta*, *chlorophyta*, *bryophyta*, *tracheophyta* etc.).

**Animalia :** They are multicellular eukaryotic organisms having holozoic type of nutrition. They show muscular contractility and have a nervous system.



**Fig :1.1-1 Probable phylogenetic relationships among the kingdoms**

**Taxonomic Aids :** Taxonomists collect specimens from the field, preserve and store the same for later verification and reference. Studies are carried out both in the field as well as inside the laboratory. Botanical gardens, herbaria, museums and zoological parks are important aids in taxonomic studies.

**Monograph :** It is a book or essay which gives comprehensive account of all the available information about a

genus, family or higher category (or any other particular subject) of grouping at the time of its publication. It is a highly useful taxonomic aid.

**Herbarium** : Herbaria are collections of dry, pressed and preserved plant specimens mounted on sheets. Some plant parts are also kept in preservative liquids if they cannot be dried and pressed.

**Botanical Gardens** : These specialized gardens have collections of living plants for reference. Plant species in these gardens are grown for identification purposes and each plant is labelled indicating its botanical/scientific name and its family. The famous botanical gardens are at Kew (England), Indian Botanical Garden, Howrah (India) and at National Botanical Research Institute Lucknow (India).

**Museum** : Biological museums are generally set up in educational institutes such as schools and colleges. Museums have collections of preserved plant and animal specimens for study and reference. Plant and animal specimens may also be preserved as dry specimens. Specimens are preserved in the containers or jars in preservative solutions. Insects are preserved in insect boxes after collecting, killing and pinning. Larger animals like birds and mammals are usually stuffed and preserved. The largest museum in our country is Indian Museum at Kolkata.

**Zoological Parks** : These are the places where wild animals are kept in protected environments under human care and which enable us to learn about their food habits and behaviour. All animals in a zoo are provided, as far as possible, the conditions similar to their natural habitats.

## Tips & Tricks

✚ Founder of Taxonomy : Aristotle.

✚  $\alpha$ -taxonomy (Turill, 1938) based on collections identification, compilation of fauna and flora.

✚  $\omega$  (omega) taxonomy (Turill, 1938) : It brings out the correct relationships as in new systematics.

✚ Cladistics is a method of classification (given by Willi Hennig) in which plants/animals are placed into taxonomic groups (called clades) according to their phylogenetic/ evolutionary relationships.

✚ Cladogram : Tree like graphic representation of evolutionary history of organism.

✚ Dendrogram : When cladogram is based on numerical taxonomy it is called dendrogram.

✚ Tribe : An intermediate category which is used in between genus and sub family.

✚ Cohort : Used differently by different authors as (i) Group of related species (ii) Group between order and class and (iii) Group above the rank of super-order.

✚ Taxonomic key : It is a set of alternate characters of different types arranged sequence wise in such manner that by selection and elimination one can quickly find out the same organism. It is of two type : (a) Bracketed key (b) Indented or yolked key.

✚ Floral characters are used as basis of classification and for identifying new species because floral characters are conservative when compared with vegetative characters.

✚ In Bentham and Hooker's classification Dicotyledons have been kept before Monocotyledons. Seed plants have been divided into Dicots, Gymnospermae and Monocots.

✚ Among the vegetative characters, venation in leaf in one of highly acceptable character for classification of angiosperms.

✚ The correct sequence of taxa in Linnaean hierarchy is species  $\rightarrow$  genus  $\rightarrow$  family  $\rightarrow$  order  $\rightarrow$  class

✚ Bauhin (1623) proposed the binary system of nomenclature which was elaborated by Linnaeus (1753) into binomial system.

✚ Monotypic genus : A genus having only one species, e.g., *Homo*.

✚ Polytypic genus : A genus containing more than one species, e.g., *Panthera*, *Solanum*.

✚ Engler and Prantl wrote 'Die naturlichen pflanzen familien' which contained the first phylogenetic classification.

✚ J.K. Maheswari described the plants of India in 'Flora of Delhi'.

✚ Camerarius was the person, who first recognized sexuality in plants.

✚ In Bentham and Hooker's system of classification, evolutionary criteria have not been followed hence not phylogenetic.

✚ Phylum covers the largest number of organisms.

✚ Hooker compiled first complete flora of India and wrote the book 'Flora of British India'.

✚ The prokaryotes and eukaryotes were distinguished by Dogherty (1957).

# OT Ordinary Thinking

## Objective Questions

### Nature and Scope of Biology

- A prediction made by a scientist based on his observations is known as [Kerala PMT 2003]
  - Law
  - Theory
  - Principle
  - Hypothesis
- Melvin Calvin was professor of [AMU (Med.) 2012]
  - Botany
  - Plant physiology
  - Chemistry
  - Biochemistry
- The study of trends in human population growth and the prediction of future development is known as [Kerala PMT 2000]
  - Sociology
  - Geography
  - Demography
  - Anthropology
- Aquaculture does not include [BHU 2003]
  - Pisces
  - Prawns
  - Silkworm
  - Shell fishery
- Edaphology is [KCET 2007]
  - Study of elephants
  - Study of snakes
  - Study of amphibians
  - None of these
- Animals that rely on the heat from the environment, rather than of metabolism, to raise their body temperature are, in the strict sense, called [AMU (Med.) 2010]
  - Ectothermic
  - Poikilothermic
  - Homeothermic
  - Endothermic
- Study of ecology of population is called [MP PMT 2007]
  - Autecology
  - Synecology
  - Ecotype
  - Demecology
- Branch of Zoology dealing with the study of fishes is known as [KCET 1994, 99; Bihar MDAT 1995; BCECE 1995; Odisha JEE 2002; MP PMT 2009]
  - Herpetology
  - Ichthyology
  - Mammalogy
  - Ornithology
- Science that deals with the study of external form, size, colour, structure and relative position of various parts of an organism is known as [Odisha JEE 2012]
  - Ecology
  - Taxonomy
  - Anatomy
  - Morphology
- In which type of isolation, two species living in different habitats are prevented from interbreeding [J & K CET 2010]
  - Temporal
  - Ecological
  - Behavioural
  - Gametic
- The study of action of drug is known as [MP PMT 2001]
  - Physiology
  - Pharmacology
  - Pharmacognosy
  - Pharmaceutical chemistry
- Study of periodical changes in plants in relation to seasonal changes [DPMT 2006, 10]
  - Physiognomy
  - Phycology
  - Phenology
  - Photoperiodism
- Bioinformatics is an interdisciplinary branch which is concerned with the application of [KCET 2006]
  - Engineering techniques in biological studies
  - Chemistry in understanding the biological phenomenon
  - Physics in understanding various life processes
  - Information science in analyzing the biological data
- In medical science, the study of structure as well as various disorders of nervous system is termed as [Odisha JEE 2012]
  - Neurology
  - Gynaecology
  - Cardiology
  - Endocrinology
- The term "biology" was introduced by [MP PMT 1995]
  - Aristotle
  - Darwin
  - Lamarck and Treviranus
  - Linnaeus
- The scientist who cut the tail of mouse in many generations but found that it is not inherited [CPMT 1995]
  - Darwin
  - Bateson
  - Lamarck
  - Weismann
- Who is called 'Father of Zoology' [MP PMT 1999]
  - Aristotle
  - Darwin
  - Hippocrates
  - Theophrastus
- Biometry refers to [AFMC 2012]
  - Measurement of evolutionary rate in humans
  - Measurement of living things and processes
  - Measurement of fertility and mortality rate
  - None of these
- 'Father of Botany' is [Odisha JEE 2004, 11]
  - Brunfels
  - Aristotle
  - Theophrastus
  - Linnaeus
- K. Esau dominated in the field of plant biology up to the age of 99 years. She contributed mainly in the field of [AMU (Med.) 2012]
  - Morphology of flowering plants
  - Anatomy of seed plants
  - Classification of flowering plants
  - Physiology of seed plants
- Study of behaviour of animals is called [RPMT 1996; BHU 2004]
  - Ethology
  - Parapsychology
  - Euphenics
  - Etiology
- William Harvey is known for the discovery of [HPMT 1993; Manipal 1996; AMU (Med.) 2000]
  - Digestion
  - Respiration
  - Blood clotting
  - Blood circulation
- The statement 'Nothing in biology makes sense except in the light of evolution' was given by [Kerala PMT 2000]
  - A.I. Oparin
  - Th. Dobzhansky
  - Joseph Hooker
  - Charles Darwin
- Study of fruit is known as [Odisha JEE 2010]
  - Pomology
  - Palynology
  - Dendrology
  - Anthology
- In history of biology, human genome project led to the development of [NCERT; CBSE PMT (Mains) 2011]
  - Bioinformatics
  - Biosystematics
  - Biotechnology
  - Biomonitoring

26. Hybridoma technology was developed by [MP PMT 2001]  
(a) Taggart, 1982 (b) Vitella *et al.*, 1982  
(c) Prie and Saxton, 1987 (d) Milstein and Kohier, 1975
27. Crick, one of the discoverer of DNA double helical structure, was the man of [NCERT]  
(a) Physics (b) Chemistry  
(c) Zoology (d) Botany
28. First experiment related to the method of hydroponics were done by [Kerala PMT 2000]  
(a) Knop (b) Hill  
(c) Arnon (d) Sachs
29. Which branch study about remains of plant life [Odisha JEE 1997; RPMT 2002; AFMC 2004]  
(a) Palaentology (b) Palaeobotany  
(c) Eugenics (d) Palynology
30. Name the scientist who was awarded the Nobel Prize for his genetic studies on the linear arrangement of genes on the chromosomes in the fruitfly, *Drosophila melanogaster* [Kerala PMT 2001]  
(a) C.F. Wolff (b) T.A. Knight  
(c) J. Swammerdam (d) T. H. Morgan
31. Who wrote the book 'Genetics and Origin of Species' [MP PMT 1999; Pb. PMT 1999]  
(a) R.A. Fisher (b) G L. Stebbins  
(c) Th. Dobzhaansky (d) J.B.S. Haldane
32. Study of Ticks and Mites is called [MP PMT 2002; Odisha JEE 2005]  
(a) Acarology (b) Entomology  
(c) Malacology (d) Carcinology
5. The type of bond involved in the formation of sodium chloride is [Kerala PMT 2009]  
(a) Ester bond (b) Peptide bond  
(c) Ionic bond (d) Covalent bond  
(e) Hydrogen bond
6. Animals spending winter in dormant conditions is referred as under [J & K CET 2005; RPMT 2005]  
(a) Hibernation (b) Aestivation  
(c) Mimicry (d) Camouflage
7. The type of linkage present in carbohydrates is [CPMT 2005]  
(a) Peptide (b) Glycosidic  
(c) Amide (d) Phosphate bonds
8. In ATP high energy bond is present [AMU (Med.) 2001; KCET 2002; CPMT 2005]  
(a) Between nucleoside and phosphate group  
(b) Between sugar and phosphate group  
(c) Between base (Adenine) and phosphate group  
(d) None of these
9. Anabolism is [BHU 2000]  
(a) Endergonic process (b) Exergonic process  
(c) Bidirectional process (d) Destructive process
10. Which of the following is a trace element required only in small amounts by most living things  
(a) Oxygen (b) Iron  
(c) Nitrogen (d) Hydrogen
11. The bond formed between the first phosphate group and adenosine in ATP is [KCET 2001]  
(a) Phosphoester bond (b) Adenophosphate bond  
(c) Nitrophosphate bond (d) Phosphoanhydride bond
12. Carbohydrates, the most abundant biomolecules on earth, are produced by [CBSE PMT 2005]  
(a) Some bacteria, algae and green plant cells  
(b) Fungi, algae and green plant cells  
(c) All bacteria, fungi and algae  
(d) Viruses, fungi and bacteria
13. Which of the following chemical characteristics is not common to all living beings [Manipal 2003]  
(a) Type of protein present in the body  
(b) Similar triple code for amino acids  
(c) Energy is stored by high phosphate bonds  
(d) Ribosomes are the sites of protein synthesis
14. Some plants having pleasant odour and attractive colours for [HPMT 2000]  
(a) Hydrophily (b) Anemophily  
(c) Entomophily (d) None of these
15. Metabolism comprises [NCERT]  
(a) Digestion of food  
(b) Elimination of wastes  
(c) Exchange of gases  
(d) Various energy exchanges in cell
16. Biological organisation starts with [NCERT; CBSE PMT 2007]  
(a) Submicroscopic molecular level  
(b) Cellular level  
(c) Organismic level  
(d) Atomic level

### Understanding Life

1. Which one of the following aspects is an exclusive characteristic of living things [NCERT; CBSE PMT (Mains) 2011]  
(a) Perception of events happening in the environment and their memory  
(b) Increase in mass by accumulation of material both on surface as well as internally  
(c) Isolated metabolic reactions occur in vitro  
(d) Increase in mass from inside only
2. Organisms which display properties of both living and nonliving [AFMC 2000]  
(a) Viruses (b) Diatoms  
(c) Lichens (d) Bacteria
3. When spontaneous process occurs then free energy of a system [DPMT 2003]  
(a) Decreases  
(b) Increases  
(c) Remains same  
(d) Either can decrease or increase
4. A molecule is reduced means it [Odisha JEE 2008, 09]  
(a) Loses electron  
(b) Gains proton  
(c) Loses proton and electrons  
(d) Gains electron

17. The total heat content of a system is [KCET 2002]  
 (a) Entropy (b) Free energy  
 (c) Enthalpy (d) Kinetic energy
18. Which of the following is the main adaptation for a plant to survive in xerophytic condition [HPMT 2000]  
 (a) Spines (b) No stomata  
 (c) Stipular leaves (d) None of the above
19. The energy transformation in the nervous system is [Kerala PMT 2002]  
 (a) Chemical to radiant (b) Chemical to electrical  
 (c) Chemical to mechanical (d) Mechanical to radiant
20. The most abundant compound in living cells is  
 (a) Carbon (b) Water  
 (c) Hydrogen (d) Oxygen
21. The amount of usable energy that is available for doing work in a system is  
 (a) Mechanical energy (b) Free energy  
 (c) Spontaneous energy (d) Light energy
22. Which statement is correct for biomolecules [RPMT 2001]  
 (a) DNA is a polymer of ribonucleotides  
 (b) All carbohydrates break down into glucose  
 (c) RNA is single stranded and contain different purine base than DNA  
 (d) Sequence of amino acids determine primary structure of proteins
23. Reproduction of immature or larval stage of animals caused by the acceleration of maturation is called  
 (a) Cladogenesis (b) Paedogenesis  
 (c) Morphogenesis (d) Parthenogenesis
24. Cause of mimicry is [CBSE PMT 2002]  
 (a) Isolation (b) Attack  
 (c) Protection (d) Both (b) and (c)
25. Which one is hexose sugar [BCECE 2001]  
 (a) Mannose (b) Galactose  
 (c) Both (a) and (b) (d) Cellulose
26. Maltose, lactose and sucrose are [BHU 2001]  
 (a) Disaccharides (b) Trisaccharides  
 (c) Monosaccharides (d) Polysaccharides
27. Glycogen is most structurally similar to  
 (a) Glucose (b) Starch  
 (c) Maltose (d) Cellulose
28. Which of the following is produced only by plants  
 (a) Starch (b) Glycogen  
 (c) Cholesterol (d) Triglycerides
29. The living organisms can be unexceptionally distinguished from the non-living things on the basis of their ability for [NCERT; CBSE PMT 2007]  
 (a) Responsiveness to touch  
 (b) Interaction with the environment and progressive evolution  
 (c) Reproduction  
 (d) Growth and movement
30. Which one of the following sequences is true [Pb. PMT 2000; VVMC Safdarjung 2001]  
 (a) Observations, problem defining, hypothesis, experiment  
 (b) Experiment, hypothesis, problem defining, observation  
 (c) Observation hypothesis problem defining, experiment  
 (d) Problem defining, observation, hypothesis, experiment
31. The process in which excess energy is lost by light waves is called [JIPMER 2002]  
 (a) Photolysis (b) Fluorescence  
 (c) Photo-oxidation (d) Photophosphorylation
32. Among the energy values or nutrients, 9.3 calories is that of [JIPMER 2002]  
 (a) Fats (b) Proteins  
 (c) Vitamins (d) Carbohydrates
33. Lipids are generally  
 (a) A high energy source (b) Hydrophobic  
 (c) Composed of fatty acids (d) All of the above
34. There is an exchange of materials and energy between living organisms and their surrounding. Such a system is called  
 (a) Open system (b) Closed system  
 (c) Isolated system (d) All of these
35. The basis of life (secret of life) is [AFMC 2002]  
 (a) Lipid (b) Protein  
 (c) Nucleic acid (d) Nucleoprotein
36. A coconut high in a palm tree has.....owing to its location  
 (a) Free energy (b) Kinetic energy  
 (c) Activation energy (d) Potential energy
37. Maintenance of internal favourable conditions, despite changes in external environment is [AFMC 1999; AMU (Med.) 2000; DPMT 2001; Kerala PMT 2001, 03]  
 (a) Entropy (b) Steady state  
 (c) Enthalpy (d) Homeostasis
38. Study the four statements (A – D) given below and select the two correct ones out of them  
 (A) Definition of biological species was given by Ernst Mayr  
 (B) Photoperiod does not affect reproduction in plants  
 (C) Binomial nomenclature system was given by R. H. Whittaker  
 (D) In unicellular organisms, reproduction is synonymous with growth
- The two correct statements are [NEET (Phase-II) 2016]  
 (a) (A) and (B) (b) (B) and (C)  
 (c) (C) and (D) (d) (A) and (D)

### Systematics

1. The science of naming the plant is known as  
 (a) Classification (b) Identification  
 (c) Nomenclature (d) Taxonomy
2. The branch of Botany concerned with the classification, nomenclature and identification of plants is [NCERT]  
 (a) Systematic Botany (b) Ecology  
 (c) Morphology (d) Physiology

3. Which one of the following is not a correct statements [NEET 2013]  
 (a) Key is taxonomic aid for identification of specimens  
 (b) Herbarium houses dried, pressed and preserved plant specimens  
 (c) Botanical gardens have collection of living plants for reference  
 (d) A museum has collection of photographs of plants and animals
4. A person who studies about the origin, evolution and variations in plants and also about the classification of plants, is called as [NCERT; AIIMS 1992]  
 (a) Classical taxonomist (b) Herbal taxonomist  
 (c)  $\alpha$ -taxonomist (d)  $\beta$ -taxonomist
5. ICBN stands for [NCERT; MP PMT 2003; BVP 2004; CBSE PMT 2007]  
 (a) International Council for Botanical Nature  
 (b) International Code of Botanical Nomenclature  
 (c) Indian Code of Botanical Nomenclature  
 (d) None of the above
6. Who amongst the following is regarded as the "Father of Taxonomy" [NCERT; DPMT 1992; MP PMT 1997; HPMT 1998; WB JEE 2012]  
 (a) Takhtajan (b) Linnaeus  
 (c) Bentham and Hooker (d) Theophrastus
7. If a botanist has to nomenclate a similar species, he will use [CPMT 1999; JIPMER 2001]  
 (a) Syntype (b) Neotype  
 (c) Mesotype (d) Isotype
8. Which of the following taxonomical ranks contain organisms least similar to one another [NCERT; DPMT 1999; Pb. PMT 2000]  
 (a) Class (b) Genus  
 (c) Family (d) Species
9. In a hierarchical system of plant classification, which one of the following taxonomic ranks generally ends in 'ceae' [AFMC 2003]  
 (a) Family (b) Genus  
 (c) Order (d) Class
10. Which one of the following is a taxonomical aid for identification of plants and animals based on similarities and dissimilarities [Kerala PMT 2012]  
 (a) Flora (b) Keys  
 (c) Monographs (d) Catalogues  
 (e) Manuals
11. When organism is in same class but is not in same family, the taxonomic term is called as [NCERT; Odisha JEE 2008]  
 (a) Order (b) Genus  
 (c) Species (d) Family
12. Which is a taxon [NCERT; CBSE PMT 1992; Pb. PMT 1998]  
 (a) Genera (b) Family  
 (c) Class (d) None of these
13. A group of plants with similar traits of any rank is [NCERT; CBSE PMT 1990, 92, 96, 97; AFMC 1994; CPMT 1996; Chd. CET 2000; Pb. PMT 2002; DPMT 2006; Odisha JEE 2009]  
 (a) Species (b) Genus  
 (c) Order (d) Taxon
14. Animals are classified into hierarchical group, in which one of the following the largest number of species is found [WB JEE 2012]  
 (a) Genus (b) Order  
 (c) Family (d) Cohort
15. In Botanical nomenclature of plants [NCERT; MP PMT 1993]  
 (a) Genus is written after the species  
 (b) Both in genus and species the first letter is a capital letter  
 (c) Genus and species may be same name  
 (d) Both genus and species are printed in italics
16. Match the following  
 (A) Genera Plantarum (1) Aristotle  
 (B) Species Plantarum (2) Linnaeus  
 (C) Historia Generalis Plantarum (3) Bentham and Hooker  
 (D) Scala Naturae (4) Pliny  
 (5) John Ray  
 [CBSE PMT 1999, 2001; AIEEE Pharmacy 2004; Odisha JEE 2004; WB JEE 2008; VITEEE 2008]  
 (a) A - 4, B - 2, C - 5, D - 3  
 (b) A - 4, B - 2, C - 1, D - 3  
 (c) A - 4, B - 2, C - 3, D - 1  
 (d) A - 3, B - 2, C - 5, D - 1
17. The smallest taxon is called [NCERT; J & K CET 2008; MP PMT 2010, 11]  
 (a) Class (b) Order  
 (c) Genus (d) Species
18. A system of classification in which a large number of traits are considered is [NCERT; AIIMS 1996; CBSE PMT 1999]  
 (a) Artificial system (b) Synthetic system  
 (c) Natural system (d) Phylogenetic system
19. In Bentham and Hooker's classification what was positioned in between dicots and monocots [AFMC 2008]  
 (a) Gymnosperms (b) Bryophytes  
 (c) Algae (d) Pteridophytes
20. Who proposed the Binomial Nomenclature System [NCERT; RPMT 1992, 98; CBSE PMT 1993, 94; AMU (Med.) 1995, 98, 2000; Pb. PMT 1998, 99, 2000; CPMT 1999, 2000; KCET 1999, 2000; J & K CET 2000; Wardha 2000; AIIMS 2001; MHCET 2001, 02, 04; BVP 2002; MP PMT 2003, 06; Odisha JEE 2004, 11; DPMT 2004; BHU 2005, 06; AFMC 2010]  
 (a) Whittaker (b) Mendel  
 (c) Carl Linnaeus (d) Tippo



21. New Systematics introduced by Sir Julian Huxley is also called [Kerala PMT 2008]  
 (a) Phenetics (b) Cladistics  
 (c) Biosystematics (d) Numerical taxonomy  
 (e) Chemotaxonomy
22. Binomial nomenclature system of Linnaeus means that every organism has [NCERT; CBSE PMT 1993, 94; BHU 1994, 2002; RPMT 1995; CPMT 1995; APMEE 1995; EAMCET 1995; AMU (Med.) 1995; DPMT 1996; Chd. CET 2000; Pb PMT 2000; MP PMT 2004, 06, 12; PET (Pharmacy) 2013]  
 (a) One name given by two scientists  
 (b) Two names one Latin and other of a person  
 (c) Two names one scientific and other popular  
 (d) One scientific name with generic and other with specific epithet
23. Which of the following is a merit in the Bentham and Hooker's system of classification [Kerala PMT 2008]  
 (a) The position of Gymnospermae in between dicots and monocots  
 (b) Closely related families are placed apart  
 (c) The placement of family asteraceae in the beginning of gamopetalae  
 (d) The placement of order ranales in the beginning  
 (e) The placement of orchidaceae in microspermae
24. Linnaeus system of plant classification is [NCERT; MP PMT 1996, 97; AIIMS 1999; Kerala PMT 2004]  
 (a) Artificial (b) Natural  
 (c) Phylogenetic (d) None of the above
25. In plants Latin names are suggested because  
 (a) Latin is a simple language  
 (b) In whole world there would be only one name for one plant  
 (c) It is easy to write  
 (d) Most of the names in other languages are not correct
26. Specific epithet is [Odisha JEE 2012]  
 (a) First word in the scientific name of a species  
 (b) Second word in the scientific name of a species  
 (c) Both (a) and (b)  
 (d) None of these
27. Who did propose natural classifications of plants [NCERT; CPMT 1992, 2009; MHCET 2002; Odisha JEE 2004, 09; BVP 2004; KCET 2012]  
 (a) Carolus Linnaeus (b) John Hutchinson  
 (c) Bentham and Hooker (d) Oswald Tippo
28. Who proposed phylogenetic classification of plants [NCERT; BHU 1991; CPMT 1998; Haryana PMT 2000; Pb. PMT 2004]  
 (a) Linnaeus (b) Hutchinson  
 (c) Bentham and Hooker (d) Mehta
29. Identify from the following, the only taxonomic category that has a real existence. [KCET 2006]  
 (a) Genus (b) Species  
 (c) Phylum (d) Kingdom
30. Five kingdom classification was proposed by [NCERT; Haryana PMT 1993; AFMC 1994; MP PMT 2000, 06; MHCET 2001; BVP 2001; Kerala PMT 2004; Odisha JEE 2004; J & K CET 2010; CPMT 2010]  
 (a) Birbal Sahni (b) Whittaker  
 (c) Aristotle (d) Oswald Tippo
31. In Whittaker's 'Five Kingdom Classification', eukaryotes were assigned to [NCERT; BHU 1994; KCET 1999; MHCET 2003; Odisha JEE 2005]  
 (a) Only two of the five kingdoms  
 (b) Only three of the five kingdoms  
 (c) Only four of the five kingdoms  
 (d) All the five kingdoms
32. In five kingdom system, the main basis of classification is [NCERT; Manipal 2001; CBSE PMT 2002]  
 (a) Nutrition (b) Nucleus structure  
 (c) Cell wall structure (d) Asexual reproduction
33. Brinjal, potato, tomato, onion, ginger belongs to [Odisha JEE 2009]  
 (a) Single family (b) Species  
 (c) Genera (d) Same genus
34. Two kingdoms constantly figured in all biological classifications are [J & K CET 2008]  
 (a) Plantae and animalia (b) Monera and animalia  
 (c) Protista and animalia (d) Protista and plantae
35. Which of the following is grouped under phanerogams [CBSE PMT 2000]  
 (a) Pteridophytes (b) Gymnosperms  
 (c) Angiosperms (d) Both (b) and (c)
36. Single-celled eukaryotes are included in [NCERT; DUMET 2009; CBSE PMT (Pre.) 2010; BHU 2012]  
 (a) Monera (b) Protista  
 (c) Fungi (d) Archaea
37. No. of plants species reported in India are [DPMT 2003]  
 (a) 45,000 (b) 40,000  
 (c) 90,000 (d) 50,000
38. Genus is a group of similar and related [Pb. PMT 2000]  
 (a) Order (b) Genera  
 (c) Families (d) Species
39. Which of the following is excluded in Whittaker's five kingdom system of classification [BHU 2012]  
 (a) Viruses (b) Algae  
 (c) Fungi (d) Bacteria
40. Systema Naturae is concerned with [MP PMT 1998]  
 (a) Solar system  
 (b) Ecosystem  
 (c) Classification of plants and animals  
 (d) Natural selection
41. Which of the following are correctly matched with respect to their taxonomic classification [NEET 2013]  
 (a) Spiny anteater, sea urchin, sea cucumber – Echinodermata  
 (b) Flying fish, cuttlefish, silverfish – Pisces  
 (c) Centipede, millipede, spider, scorpion – Insecta  
 (d) Housefly, butterfly, tsetsefly, silverfish – Insecta

42. The meaning of taxon in the classification of animals  
[CBSE PMT 1996]  
(a) A group of same species  
(b) A group of animals on the basis of number of chromosomes  
(c) A group of same type of animals  
(d) A group of similar genera
43. Most important criteria used for the present day classification of living organisms is based on [CBSE PMT 1991]  
(a) Presence and absence of notochord  
(b) Resemblances in external features  
(c) Breeding habits  
(d) Anatomical and physiological characteristics
44. The non-nucleated, unicellular organisms of Whittaker's (1969) classification are included in the kingdom  
[NCERT; MP PMT 1994; BHU 1997, 2012; Kerala PMT 2000; J & K CET 2008; AMU (Med.) 2010]  
(a) Protista (b) Monera  
(c) Animalia (d) Plantae
45. The suffix 'idae' refers to  
(a) Family (b) Genus  
(c) Order (d) Division
46. Read the statements given below and identify the incorrect statement [KCET 2012]  
(a) Scientific names are used all over the world  
(b) Scientific names are often descriptive and tell us some important character of an organism  
(c) Scientific names indicate relationship between species  
(d) Scientific names favour multiple naming for the same kind of an organism
47. The term 'New systematics' was introduced in 1940 by [AFMC 1993; AMU (Med.) 1999; BVP 2002]  
(a) Adolf Engler (b) Karl prantl  
(c) George Bentham (d) Julian Huxley
48. Taxonomic hierarchy refers to [DUMET 2009]  
(a) Stepwise arrangement of all categories for classification of plants and animals  
(b) A group of senior taxonomists who decide the nomenclature of plants and animals  
(c) A list of botanists or zoologists who have worked on taxonomy of a species or group  
(d) Classification of a species based on fossil record
49. The third name of the trinomial nomenclature is of [NCERT; JIPMER 1993; APMEET 2001]  
(a) Sub-genus (b) Species  
(c) Sub-species (d) Type
50. In which book has "binomial nomenclature" been used for the first time [MP PMT 1999; Pb PMT 1999; Odisha JEE 2005]  
(a) Histoire naturelle (b) Systema naturae  
(c) Historia naturalis (d) Historia plantarum
51. Who developed the "key" for identification of animals [MP PMT 1999]  
(a) John Ray (b) Goethe  
(c) Georges Cuvier (d) Theophrastus
52. What is the name of the book written by Aristotle [MP PMT 1999; Pb PMT 1999]  
(a) Historia Animalium (b) Histoire Naturelle  
(c) Systema Naturae (d) Philosophic Zoologique
53. The replacement of two kingdoms grouping by five kingdom classification was proposed in the year [Kerala CET 2003]  
(a) 1859 (b) 1758  
(c) 1919 (d) 1969
54. Engler and Prantl published a phylogenetic system in monograph [Kerala CET 2005]  
(a) Die Naturlichen Pflanzen Familien  
(b) Historia Plantarum  
(c) Species Plantarum  
(d) Genera Plantarum  
(e) Origin of Species
55. In the five-kingdom classification, *Chlamydomonas* and *Chlorella* have been included in [NCERT; CBSE PMT (Mains) 2012]  
(a) Protista (b) Algae  
(c) Plantae (d) Monera
56. Which structure is present in both prokaryotic and eukaryotic plant cells [WB JEE 2008]  
(a) Cell wall (b) Nucleus  
(c) Chloroplast (d) Mitochondria
57. *Oryza sativa* is the binomial name of the rice plant, the *sativa* stands for [NCERT; WB JEE 2008]  
(a) Specific name (b) Specific epithet  
(c) Species name (d) Specific nomenclature
58. Which of the following is considered as neither prokaryotes nor eukaryotes [J & K CET 2010]  
(a) Bacteriophages (b) Bacteria  
(c) Monera (d) Fungi
59. Interbreeding natural population of animals are referred to as belonging to the same [NCERT; AMU (Med.) 2002; J & K CET 2010]  
(a) Family (b) Species  
(c) Genus (d) Variety
60. Natural system of classification is based on [NCERT; DPMT 1993]  
(a) Morphology (b) Phylogeny  
(c) Morphology and affinities (d) Ontogeny
61. Which one of the following organisms is scientifically correctly named, correctly printed according to the International Rules of Nomenclature and correctly described [NCERT; CBSE PMT (Mains) 2012]  
(a) *Musca domestica* - The common house lizard, a reptile  
(b) *Plasmodium falciparum* - A protozoan pathogen causing the most serious type of malaria  
(c) *Felis tigris* - The Indian tiger, well protected in Gir forests  
(d) *E.coli* - Full name *Entamoeba coli*, a commonly occurring bacterium in human intestine

62. Consider the following statements with respect to characteristic features of the kingdom  
 A. In animalia the mode of nutrition is autotrophic  
 B. In monera the nuclear membrane is present  
 C. In protista the cell type is prokaryotic  
 D. In plantae the cell wall is present  
 Of the above statements [Kerala PMT 2012]  
 (a) A alone is correct (b) B alone is correct  
 (c) C alone is correct (d) D alone is correct  
 (e) A, B and C are correct
63. Cohort is a group correlated with [MHCET 2004]  
 (a) Species (b) Genera  
 (c) Families (d) Order
64. International code of "Biological nomenclature" is applicable to  
 (a) Plants (b) Animals  
 (c) Both animals and plants (d) None of the above
65. The term "phylum" in animal classification was coined by [CBSE PMT 1992; MP PMT 1994, 2010]  
 (a) E. Haeckel (b) John Ray  
 (c) G.L. Cuvier (d) Carolus Linnaeus
66. Family is placed between [Odisha JEE 2011]  
 (a) Order and genus (b) Genus and species  
 (c) Class and order (d) Phylum and class
67. Four kingdom classification was proposed by [HPMT 1994; BHU 1994]  
 (a) Whittaker (b) Copeland  
 (c) Haeckel (d) Linnaeus
68. Five kingdom system of classification suggested by R.H. Whittaker is not based on [CBSE PMT 2014]  
 (a) Mode of nutrition  
 (b) Complexity of body organization  
 (c) Presence or absence of a well defined nucleus  
 (d) Mode of reproduction
69. Cytotaxonomy is connected with [NCERT]  
 (a) Chemical composition of cytoplasm  
 (b) Cell organelles  
 (c) Cytochromes  
 (d) Shape and size of cells
70. 'Taxa' differs from 'taxon' due to [DUMET 2010]  
 (a) This being a higher taxonomic category than taxon  
 (b) This being lower taxonomic category than taxon  
 (c) This being the plural of taxon  
 (d) This being the singular of taxon
71. The term 'biosystematics' was coined by [J & K CET 2010; MP PMT 2010, 12]  
 (a) Gaspard Bauhin (b) Camp and Gilly  
 (c) Karl Prantl (d) Robert Brown
72. Which of the following statements regarding universal rules of nomenclature is wrong [Kerala PMT 2010; NEET (Phase-I) 2016]  
 (a) The first word in a biological name represents the genus  
 (b) The first word denoting the genus starts with a capital letter  
 (c) Both the words in a biological name, when handwritten, are separately underlined  
 (d) Biological names are generally in Greek and can be written in any language  
 (e) The second component in a biological name denotes the specific epithet
73. A scientist having made significant contribution in the field of classification is [CPMT 1990]  
 (a) Pasteur (b) Oparin  
 (c) Darwin (d) Linnaeus
74. Classical systematics embodies/concept of classical taxonomist is [JIPMER 1997]  
 (a) Biological concepts (b) Species concept  
 (c) Typological concept (d) All the above
75. Species is [CBSE PMT 1994]  
 (a) Specific unit of evolution  
 (b) Specific unit in the evolutionary history of a race  
 (c) Specific class of evolution  
 (d) Not related to evolution
76. Two plants are taxonomically related if [NCERT]  
 (a) They store carbohydrate in the same type of molecule  
 (b) Both obtain energy from hydrolysis of ATP into ADP and inorganic phosphate  
 (c) Both have similarly lobed palmate leaves  
 (d) Both have pinnately veined leaves
77. A group of related genera, with still less number of similarities as compared to the genus and species, constitutes [NCERT; AFMC 2009; DUMET 2010]  
 (a) Order (b) Class  
 (c) Family (d) Division
78. Match the following and choose the correct combination from the options given
- | Column I<br>(Common name) |          | Column II<br>(Taxonomic category Order) |            |
|---------------------------|----------|---|------------|
| A.                        | Wheat    | 1.                                      | Primata    |
| B.                        | Mango    | 2.                                      | Diptera    |
| C.                        | Housefly | 3.                                      | Sapindales |
| D.                        | Man      | 4.                                      | Poales     |
- [Kerala PMT 2010]  
 (a) A-1, B-2, C-4, D-3 (b) A-4, B-3, C-2, D-1  
 (c) A-2, B-4, C-1, D-3 (d) A-3, B-4, C-2, D-1  
 (e) A-4, B-2, C-3, D-1
79. In the scientific name of *Mangifera indica* L.  
 (a) Letter L. signifies latin language  
 (b) The name is reverse with *indica* preceeding *mangifera*  
 (c) Letter L. signifies taxonomist Linnaeus  
 (d) Letter L. is superfluous
80. Plant classification proposed by Carolus Linnaeus was artificial because it was based on [NCERT; RPMT 1990; CPMT 1995]  
 (a) Only a few morphological characters  
 (b) Evolutionary tendencies which are diverse  
 (c) Anatomical characters which are adaptive in nature  
 (d) Physiological traits alongwith morphological characters
81. Classification of organisms based on evolutionary as well as genetic relationships is called [DUMET 2010]  
 (a) Biosystematics (b) Phenetics  
 (c) Numerical taxonomy (d) Cladistics

82. Carolus Linnaeus (Carl Linne) was from [Manipal 1997]  
 (a) Sweden (b) U.K.  
 (c) Holland (d) France
83. First act in taxonomy is [NCERT; Wardha 2002]  
 (a) Description (b) Identification  
 (c) Naming (d) Classification
84. Taxonomy based on determination of genetic relationships is [NCERT; JIPMER 1997]  
 (a) Cytotaxonomy (b) Numerical taxonomy  
 (c) Biochemical taxonomy (d) Experimental taxonomy
85. Branch connected with nomenclature, identification and classification is [CPMT 1991; AMU (Med.) 2000; Kerala PMT 2002]  
**Or**  
 The study of theory, practice and rules of classification of living and extinct organisms is called [Odisha JEE 2012]  
 (a) Ecology (b) Taxonomy  
 (c) Morphology (d) Physiology
86. Sequence of taxonomic categories is [NCERT; DPMT 1992; CBSE PMT 1992; AFMC 1992, 2001; HPMT 1994; Pb. PMT 1997; KCET 2001, 11; Kerala PMT 2007; AMU (Med.) 2012]  
 (a) Class – phylum – tribe – order – family – genus – species  
 (b) Division – class – family – tribe – order – genus – species  
 (c) Division – class – order – family – tribe – genus – species  
 (d) Phylum – order – class – tribe – family – genus – species
87. Phylogenetic system of classification is based on [NCERT; CBSE PMT 1994, 2006, 09; Pb. PMT 2000; Odisha JEE 2002; DPMT 2006]  
 (a) Evolutionary relationships  
 (b) Morphological features  
 (c) Chemical constituents  
 (d) Floral characters
88. An attribute found in plants but not animals is  
 (a) Metabolism (b) Sexual reproduction  
 (c) Autotrophy (d) Asexual reproduction
89. *Systema Naturae* was written by [CPMT 1991, 92, 93; Kerala PMT 2010; Odisha JEE 2010]  
 (a) Lamarck (b) Cuvier  
 (c) Aristotle (d) Linnaeus
90. Which of the following taxonomist described classification of plant kingdom in "Families of flowering plants" [CPMT 2004]  
 (a) Cronquist (b) Takhtajan  
 (c) Benson (d) Hutchinson
91. Mayr's biological concepts of species is mainly based on [NCERT; BVP 2004; BHU 2004, 08; CPMT 2009]  
 (a) Morphological traits  
 (b) Reproductive isolation  
 (c) Modes of reproduction  
 (d) Morphology and reproduction
92. Two morphologically similar populations are intersterile. They belong to [NCERT; BHU 1994, 97, 2000; Kerala PMT 2005]  
 (a) One species  
 (b) Two biospecies  
 (c) Two sibling species  
 (d) None of the above
93. Which one possess characters of both plants and animals [CBSE PMT 1995]  
**Or**  
 A unicellular organism often considered connecting link between plants and animals is [AFMC 1997; JIPMER 1998]  
 (a) Bacteria (b) *Mycoplasma*  
 (c) *Paramecium* (d) *Euglena*
94. Distinction of prokaryota and eukaryota is mainly based on [NCERT; MP PMT 1995, 98]  
 (a) Nucleus only (b) Cell organelles only  
 (c) Chromosomes only (d) All the above
95. Algae with photosynthetic pigments possess nutrition [AMU (Med.) 1997; Manipal 1997]  
 (a) Holozoic (b) Saprophytic  
 (c) Holophytic (d) Parasitic
96. Select the incorrect statements  
 (A) Lower the taxon, more are the characteristics that the members within the taxon share  
 (B) Order is the assemblage of genera which exhibit a few similar characters  
 (C) Cat and dog are included in the same family Felidae  
 (D) Binomial nomenclature was introduced by Carolus Linnaeus [Kerala PMT 2011]  
 (a) A, B and C (b) B, C and D  
 (c) A and D (d) C and D  
 (e) B and C
97. Phylogenetic system was given [DPMT 2007; Kerala PMT 2009; CPMT 2010]  
 (a) Engler & Prantl (b) Pliny  
 (c) John Ray (d) R.H. Whittaker
98. Huxley is father of [MP PMT 2007]  
 (a) Classical taxonomy (b) Artificial taxonomy  
 (c) Neo-taxonomy (d) Adansonian taxonomy
99. Species can be identified on the basis of [MP PMT 2007]  
 (a) Interbreed (b) Species diversity  
 (c) Reproductive isolation (d) None of these
100. In the five kingdom system of classification, which single kingdom out of the following can include blue-green algae, nitrogen fixing bacteria and methanogenic archaeobacteria [NCERT; CBSE PMT 1998; Pb. PMT 1998]  
 (a) Monera (b) Fungi  
 (c) Plantae (d) Protista
101. Floral features are commonly used for identification of angiosperms because [NCERT; CBSE PMT 1998]  
 (a) Reproductive parts are more conservative  
 (b) Flowers can be safely pressed  
 (c) Flowers are nice to work with  
 (d) Flowers have various colours and scents
102. Two similar holotypes are called [BHU 1997]  
 (a) Mesotypes (b) Meotypes  
 (c) Syntypes (d) Isotypes
103. Binomial system of nomenclature for plants is effective from [JIPMER 1997]  
 (a) 5.8.1771 (b) 1.5.1753  
 (c) 1.8.1758 (d) 6.7.1736

104. A system of classification that is based on evolution, order and ancestry is known as [Pb. PMT 1998; MP PMT 1998]  
 (a) Natural system (b) Analogous system  
 (c) Phylogenetic system (d) Homologous system
105. Characteristics which delimit a family are more general than those which delimit a [JIPMER 1999]  
 (a) Cohort (b) Phylum  
 (c) Class (d) Genus
106. First great taxonomist was [BHU 1999]  
 (a) Linnaeus (b) Hooker  
 (c) Aristotle (d) Engler
107. In the classification of plants, the term cladistics refers to the [Kerala PMT 2006; BHU 2008]  
 (a) Phylogenetic classification (b) Sexual classification  
 (c) Artificial classification (d) Natural classification  
 (e) Binomial classification
108. Five kingdom classification includes [DPMT 2006]  
 (a) Monera, Protista, Fungi, Plantae, Animalia  
 (b) Algae, Fungi, Bryophyta, Pteridophyta, Gymnosperms  
 (c) Virus, Prokaryota, Fungi, Plantae, Animalia  
 (d) Monera, Protista, Animalia, Plantae, Algae
109. Which of the following is less general in characters as compared to genus [NCERT; CBSE PMT 2001]  
 (a) Species (b) Family  
 (c) Class (d) Division
110. What is correct [NCERT; Manipal 2001; Odisha JEE 2012; KCET 2012]  
 (a) *Apis indica* (b) *trypanosoma gambiense*  
 (c) *Ficus Bengalensis* (d) *Mangifera indica*
111. Which covers the largest number of organisms [Kerala PMT 2001]  
 (a) Genus (b) Family  
 (c) Phylum (d) Class  
 (e) Order
112. Which of the following is not taxon but a category [MHCET 2000]  
 (a) Division (b) Angiosperms  
 (c) Polypetalae (d) *Hibiscus*
113. Chemotaxonomy is connected with [NCERT; MHCET 2001]  
 (a) Classification of chemicals found in plants  
 (b) Use of phytochemical data in systematic botany  
 (c) Application of chemicals on herbarium sheets  
 (d) Use of statistical methods in chemical yielding plants
114. Descending arrangements of categories is called [NCERT; MHCET 2001]  
 (a) Classification (b) Taxonomy  
 (c) Hierarchy (d) Key
115. Holotype is [Pb. PMT 2001]  
 (a) Specimen used by author as nomenclature type  
 (b) Specimen referred alongwith original description  
 (c) Duplicate of nomenclature type  
 (d) Specimen selected from original when nomenclature type is missing
116. Keystone species are [Pb. PMT 2001]  
 (a) Species belonging to same period  
 (b) Species that determine structure of biotic community  
 (c) Species reproducing sexually  
 (d) Species recorded only in the fossil state
117. *Nicotiana glauca* [NCERT; Haryana PMT 2001]  
 (a) Variety (b) Subspecies  
 (c) Species (d) Genus
118. Barophilic prokaryotes [CBSE PMT 2005]  
 (a) Grow slowly in highly alkaline frozen lakes at high altitudes  
 (b) Occur in water containing high concentrations of barium hydroxide  
 (c) Grow and multiply in very deep marine sediments  
 (d) Readily grow and divide in sea water enriched in any soluble salt of barium
119. In hierarchical classification class is interpolated between [NCERT; Chd. CET 2002]  
 (a) Family and genus (b) Phylum and order  
 (c) Order and family (d) Kingdom and phylum
120. Binomial nomenclature is [MP PMT 1997; Chd. CET 2002]  
 (a) Two words in name of a species  
 (b) Two names local and specific  
 (c) Two names of a species  
 (d) Two phases, asexual and sexual, in the life cycle of a species
121. A true species consists of a population [CBSE PMT 2002]  
 (a) Sharing the same niche  
 (b) Interbreeding  
 (c) Feeding over the same food  
 (d) Reproductively isolated
122. Species are considered as [DPMT 1997; AIIMS 2000; BHU 2001; Kerala PMT 2002; CBSE PMT 2003; MP PMT 2009]  
 (a) Real units of classification devised by taxonomists  
 (b) Real basic units of classification  
 (c) The lowest units of classification  
 (d) Artificial concept of human mind which cannot be defined in absolute terms
123. Biosystematics aims at [CBSE PMT 2003]  
 (a) Identification and arrangement of organisms on the basis of their cytological characteristics  
 (b) The classification of organisms based on broad morphological characters  
 (c) Delimiting various taxa of organisms and establishing their relationships  
 (d) The classification of organisms based on their evolutionary history and establishing their phylogeny on the totality of various parameters from all fields of study
124. Phenetic classification of organisms is based on [NCERT; CBSE PMT 2004; WB JEE 2016]  
 (a) Dendrogram based on DNA characteristics  
 (b) Sexual characteristics  
 (c) Observable characteristics of existing organisms  
 (d) The ancestral lineage of existing organisms

125. Match the following and select the correct combination from the options given below

Column I (Kingdom)		Column II (Class)	
A.	Plantae	1.	Archaeobacteria
B.	Fungi	2.	Euglenoids
C.	Protista	3.	Phycomycetes
D.	Monera	4.	Algae

[Kerala PMT 2011]

- (a) A-4, B-3, C-2, D-1  
 (b) A-1, B-2, C-3, D-4  
 (c) A-3, B-4, C-2, D-1  
 (d) A-4, B-2, C-3, D-1  
 (e) A-2, B-3, C-4, D-1
126. The term species was coined by [BVP 2002; KCET 2004]  
 (a) Aristotle (b) Engler  
 (c) John Ray (d) Linnaeus
127. The common characteristics between tomato and potato will be maximum at the level of their [NEET (Karnataka) 2013]  
 (a) Family (b) Order  
 (c) Division (d) Genus
128. The label of a herbarium sheet does not carry information on [NEET (Phase-II) 2016]  
 (a) Height of the plant (b) Date of collection  
 (c) Name of collector (d) Local names

# NCERT

## Exemplar Questions

1. As we go from species to kingdom in a taxonomic hierarchy, the number of common characteristics [NCERT]  
 (a) Will decrease (b) Will increase  
 (c) Remain same (d) May increase or decrease
2. Which of the following 'suffixes' used for units of classification in plants indicates a taxonomic category of 'family' [NCERT]  
 (a) -Ales (b) -Onae  
 (c) -Aceae (d) -Ae
3. The term 'systematics' refers to [NCERT]  
 (a) Identification and classification of plants and animals  
 (b) Nomenclature and identification of plants and animals  
 (c) Diversity of kinds of organisms and their relationship  
 (d) Different kinds of organisms and their classification
4. Genus represents [NCERT]  
 (a) An individual plant or animal  
 (b) A collection of plants or animals  
 (c) Group of closely related species of plants or animals  
 (d) None of these
5. The taxonomic unit 'Phylum' in the classification of animals is equivalent to which hierarchical level in classification of plants [NCERT]  
 (a) Class (b) Order  
 (c) Division (d) Family

6. Botanical gardens and zoological parks have [NCERT]  
 (a) Collection of endemic living species only  
 (b) Collection of exotic living species only  
 (c) Collection of endemic and exotic living species  
 (d) Collection of only local plants and animals
7. Taxonomic key is one of the taxonomic tools in the identification and classification of plants and animals. It is used in the preparation of [NCERT]  
 (a) Monographs (b) Flora  
 (c) Both (a) and (b) (d) None of these
8. All living organisms are linked to one another because [NCERT]  
 (a) They have common genetic material of the same type  
 (b) They share common genetic material but to varying degrees  
 (c) All have common cellular organization  
 (d) All of above
9. Which of the following is a defining characteristic of living organisms [NCERT]  
 (a) Growth (b) Ability to make sound  
 (c) Reproduction (d) Response to external stimuli
10. Match the following and choose the correct option [NCERT]
- |            |                     |
|------------|---------------------|
| A. Family  | i. <i>tuberosum</i> |
| B. Kingdom | ii. Polymoniales    |
| C. Order   | iii. <i>Solanum</i> |
| D. Species | iv. Plantae         |
| E. Genus   | v. Solanaceae       |
- (a) i-D, ii-C, iii-E, iv-B, v-A  
 (b) i-E, ii-D, iii-B, iv-A, v-C  
 (c) i-D, ii-E, iii-B, iv-A, v-C  
 (d) i-E, ii-C, iii-B, iv-A, v-D



## Critical Thinking

### Objective Questions

1. Karyotaxonomy is the modern branch of classification which is based on [NCERT; JIPMER 1998; MP PMT 1999]  
 (a) Number of chromosomes  
 (b) Bands found on chromosomes  
 (c) Organic evolution  
 (d) Trinomial nomenclature
2. Which of the following combinations is correct for wheat [DUMET 2010]  
 (a) Genus : *Triticum*, Family : Anacardiaceae,  
 Order : Poales, Class : Monocotyledonae  
 (b) Genus : *Triticum*, Family : Poaceae,  
 Order : Poales, Class : Dicotyledonae  
 (c) Genus : *Triticum*, Family : Poaceae,  
 Order : Sapinadales, Class : Monocotyledonae  
 (d) Genus : *Triticum*, Family : Poaceae,  
 Order : Poales, Class : Monocotyledonae

3. Hutchinson's system of classification was revised in [DPMT 2003]  
(a) 1995 (b) 1959  
(c) 1954 (d) 1946
4. The total number of species included in the animal kingdom are about [CBSE PMT 1992; DUMET 2010]  
(a) 1 million (b) 2 million  
(c) 10 million (d) 1 billion
5. Which one of the taxonomic aids can give comprehensive account of complete compiled information of any one genus or family at a particular time [NCERT; Kerala PMT 2009]  
(a) Taxonomic key (b) Flora  
(c) Herbarium (d) Monograph  
(e) Dictionary
6. A species is defined as "the group of actually or potentially inter-breeding natural population producing fertile offspring and reproductively isolated from such other groups". The above statement is given by [MP PMT 1997]  
(a) Carolus Linnaeus (b) Mayr  
(c) J.B. Lamarck (d) Charles Darwin
7. Which of the following is required as equivalent to subspecies of classical Taxonomy [VITEEE 2006]  
(a) Ecospecies (b) Ecotype  
(c) Cenospecies (d) Comparium
8. Which one of the following statement correctly define the term homonym [WB JEE 2008]  
(a) Identical name of two different taxon  
(b) Two or more names belonging to the same taxon  
(c) When species name repeats the generic name  
(d) Other name of a taxon given in a language other than the language of zoological / botanical nomenclature

## Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

- (a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion  
(b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion  
(c) If the assertion is true but the reason is false  
(d) If both the assertion and reason are false  
(e) If the assertion is false but reason is true

1. Assertion : Phylogeny is the developmental history of a species.  
Reason : Species is the basic unit of taxonomy.
2. Assertion : Whittaker's classification for algae is not acceptable.  
Reason : Whittaker grouped algae in different kingdoms.

3. Assertion : Chemotaxonomy is classifying organisms at molecular level.  
Reason : Cytotaxonomy is classifying organisms at cellular level.
4. Assertion : Whittaker did not include unicellular green algae in protista.  
Reason : Distinction between unicellular and multicellular organisms is not possible in case of algae.
5. Assertion : Systematics is the branch of biology that deals with classification of living organisms.  
Reason : The aim of classification is to group the organisms. [AIIMS 2002]
6. Assertion : Acraniata is a group of organisms which do not have distinct cranium.  
Reason : It includes small marine forms without head. [AIIMS 1997]
7. Assertion : To give scientific name to plant, there is ICBN.  
Reason : It uses articles, photographs and recommendations to name a plant. [Haryana PMT 2000]
8. Assertion : Taxon and category are same things.  
Reason : Category shows hierarchical classification.
9. Assertion : The hierarchy includes seven obligate categories.  
Reason : Intermediate categories are used to make taxonomic positions more informative.
10. Assertion : The species is reproductively isolated natural population.  
Reason : Prokaryotes cannot be kept under different species on the basis of reproductive isolation.
11. Assertion : Bacteria, Protista do not have circulatory system.  
Reason : These organisms live in moist and watery environment. [AIIMS 2010]
12. Assertion : Living organisms possess specific individuality with the definite shape and size.  
Reason : Both living and non living entities resemble each other at the lower level of organization. [AIIMS 1999]

## Answers

### Nature and Scope of Biology

1	d	2	c	3	c	4	c	5	d
6	a	7	d	8	b	9	d	10	b
11	b	12	c	13	d	14	a	15	c
16	d	17	a	18	b	19	c	20	b



## 22 The Living World

21	a	22	d	23	b	24	a	25	a
26	d	27	a	28	d	29	b	30	d
31	c	32	a						

## Understanding Life

1	a	2	a	3	a	4	d	5	c
6	a	7	b	8	d	9	a	10	b
11	b	12	a	13	a	14	c	15	d
16	a	17	c	18	a	19	b	20	b
21	b	22	d	23	b	24	d	25	c
26	a	27	b	28	a	29	c	30	a
31	b	32	a	33	d	34	a	35	c
36	d	37	d	38	d				

## Systematics

1	c	2	a	3	d	4	a	5	b
6	b	7	d	8	a	9	a	10	b
11	a	12	d	13	d	14	d	15	d
16	d	17	d	18	c	19	a	20	c
21	c	22	d	23	d	24	a	25	b
26	b	27	c	28	b	29	b	30	b
31	c	32	a	33	c	34	a	35	d
36	b	37	a	38	d	39	a	40	c
41	d	42	c	43	d	44	b	45	a
46	d	47	d	48	a	49	c	50	b
51	a	52	a	53	d	54	a	55	a
56	a	57	b	58	a	59	b	60	c
61	b	62	d	63	a	64	c	65	c
66	a	67	b	68	c	69	b	70	c
71	b	72	d	73	d	74	b	75	a
76	a	77	c	78	b	79	c	80	a
81	d	82	a	83	b	84	d	85	b
86	c	87	a	88	c	89	d	90	d
91	b	92	c	93	d	94	d	95	c
96	a	97	a	98	c	99	c	100	a
101	a	102	d	103	b	104	c	105	d
106	a	107	a	108	a	109	a	110	d
111	c	112	a	113	b	114	c	115	a
116	b	117	d	118	c	119	b	120	a
121	d	122	b	123	d	124	c	125	a
126	c	127	a	128	a				

## NCERT Exemplar Questions

1	a	2	c	3	c	4	c	5	c
6	c	7	c	8	d	9	d	10	a

## Critical Thinking Questions

1	b	2	d	3	a	4	a	5	d
6	b	7	c	8	a				

## Assertion and Reason

1	b	2	a	3	b	4	a	5	b
6	b	7	a	8	a	9	b	10	b
11	b	12	b						

## AS Answers and Solutions

## Nature and Scope of Biology

5. (d) Edaphology is study of soil.
11. (b) Pharmacology is the branch of medicine and biology concerned with the study of drug action, where a drug can be broadly defined as any man made, natural or endogenous (with in the body) molecule which exerts a biochemical and/or physiological effect on the cell, tissue, organ or organism.
12. (c) Phenology is the scientific study of seasonal changes, i.e., periodic phenomena of organisms in relation to their climate.

## Understanding Life

9. (a) In endergonic reactions, the product have more energy than the reactants, So the reaction requires an input of energy.
10. (b) Iron is component of haemoglobin of RBC of blood and helps in transportation of oxygen (about 97-99%) as well as carbon dioxide (about 23%).
16. (a) Submicroscopic particles such as Glucose amino acid, Nucleotides etc.
18. (a) Xerophytic plant of deserts, has a number of adaptation to reduce transpiration for water conservation e.g. stem is covered by thick cuticle and has high succulency while leaves are modified into spines.
20. (b) Water is the most abundant substance of living beings. In adult human body 20-22 litres (50% of the total) is present inside the cells as intracellular water.
22. (d) The shape, size, structure and biological functions of proteins are determined by the number type and arrangement of aminoacids.
24. (d) Animal imitate other animals, plants and natural objects in order to protect themselves from predators, called protective mimicry. Predatory animals mimic some natural object so that their prey get confused and is easily attacked or caught. This type of mimicry is called Agressive mimicry.

27. (b) Starch common in plant and glycogen in animals are two food storage polysaccharides. Both of them can easily be hydrolysed into their glucose monomers.
29. (c) Reproduction capacity found only in living being.
31. (b) Fluorescence is the process in which excess energy is lost by light waves. Because of this energy loss, the wavelength of the light energy released in fluorescence is generally longer than that of originally absorbed.
32. (a) Maximum energy is provided by fats (9.45 K. cal).
34. (a) A living system which can exchange the matter and energy with the environment is called an open system.

### Systematics

1. (c) Nomenclature (*Nomen* = name; *clature* = to call) is giving distinct scientific names to various structures, including living organisms, so they can be easily identified.
4. (a) Taxonomy based on all available information and attempting to classify organisms, according to their origin, evolution and variation is called classical taxonomy. A taxonomist engaged in studying origin, evolution, variations and classification of organisms is called classical taxonomist.
7. (d) Original specimen is called holotype and the duplicate of holotype is termed as isotype.
8. (a) The closely related orders are grouped into a class (named as a taxonomical rank in classification) which have least similar organisms to another.
9. (a) Family is a taxonomic category between the division and order. It includes one or more genera. Its suffix is 'aceae'.
15. (d) In botanical nomenclature of plants generic name always begin with capital letter and the specific name with a small letter and printed in italics.
18. (c) In the natural system of classification organisms are arranged according to their natural affinities through the use of all important characters. Characteristics such as structural, cytological, reproductive and biochemical are included. The characters are useful in bringing out homology.
20. (c) The 'Binomial system of nomenclature' was explained by Carl Linnaeus in his book 'species plantarum' in 1753. According to this system name of any organism/plant consist of two words. First represents its 'genera' and second its 'species'.
24. (a) Linnaeus system of classification is considered as artificial because it is based only on one or two character of plants.
31. (c) In five kingdom classification of Whittaker eukaryotes were assigned to only four of the five kingdom. Prokaryotes are included in kingdom – monera.
35. (d) Gymnosperms and angiosperms both are grouped under phanerogams because both are bearing seeds.
36. (b) Angiosperms flowering plants constitute the dominating terrestrial flora of the world is known as spermatophyta.
44. (b) Monera contains the most primitive living forms which are basically unicellular prokaryotes.
47. (d) The term new systematics was proposed by Sir Julian Huxley in 1940. In the new systematics, the species are considered related to one another mutable and the work of gradual modification. This is in conformity with the facts of evolution.
49. (c) Sometimes organisms of same species differ from each other as they are adapted for different kinds of environment. In such cases species are again divided into subspecies.
50. (b) Carolus Linnaeus introduced binomial nomenclature in his tenth edition of 'Systema naturae'.
53. (d) R.H. Whittaker (1969), an American ecologist, divide all the organisms into five kingdoms.
59. (b) An individual of a species can interbreed to produce fertile offspring.
60. (c) Natural system of classification is based on the large number of morphological characters and natural affinities of organism.
61. (b) *Plasmodium falciparum* - A protozoan pathogen causes the most serious type of malaria that is falciparum malaria.
67. (b) Four kingdom (Plantae, animalia, protista and monera) classification was developed by Copeland (1956). The main drawback of this system is that fungi are not properly placed.
68. (c) The main criteria of Whittaker's system are :- Cell type, Thallus organization, Nutrition, Reproduction and Phylogenetic relationship.
69. (b) Cytotaxonomy based on information about cytological structure, chromosomes numbers, structure and behaviour during meiosis and cell organelles.
83. (b) Identification is assigning an organism its correct name and placing it in its proper taxonomic category.
84. (d) Experimental taxonomy based on the experimental determination of the genetic relationship, environmental impact and evolutionary divergence within a group.
85. (b) Taxonomy is a branch of biology which deals with the study of principles and procedures of classification, nomenclature and identification. The term taxonomy was coined by De Candolle (1813).
87. (a) In phylogenetic system, the organisms are classified according to their evolution of genetic affinities. The system of classification proposed by Engler (1886) by Hutchinson (1926) and by Tippo (1942) are phylogenetic.
88. (c) Autotrophy is a characteristics of plants.
89. (d) In 1735, Carolus Linnaeus published the first edition of his classification of living things in his *Systema Naturae*.
90. (d) John Hutchinson put forward a classification on phylogenetic lines in the book "families of flowering plants"

91. (b) Mayr defined species as group of interbreeding natural population that are reproductively isolated from each other group.
92. (c) Sibling species : True species which do not interbreed but are otherwise difficult to separate on the basis of morphological characters alone.
95. (c) Algae with photosynthetic pigment possess photosynthetic (holophytic) nutrition.
110. (d) Because *Mangifera indica* is a correct representation of scientific name. According to binomial nomenclature.
111. (c) Phylum includes one or more related classes. All the classes of a phylum possess some common correlated traits. So the phylum covers the largest numbers of organism.
126. (c) Term species was coined by John Ray in 1693.
128. (a) The herbarium sheets carry a label providing information about date and place of collection, english, local and botanical names, family, collector's
4. (a) A distinction between unicellular and multicellular organisms is not possible in case of algae in Whittaker's system. It is because of this that unicellular green algae have not been included in kingdom protista.
5. (b) Systematics is related with classification of organisms. In classification the organisms are grouped on the basis of their characters or phylogeny, etc.
6. (b) Acraniata includes marine forms without head or cranium. They lack jaws, vertebral column, paired appendages.
7. (a) Anyone can study, describe, identify and give a name to an organism provide certain rules are followed. These rules are formed and standardised by International Code of Botanical Nomenclature (ICBN). It uses articles, photographs and recommendations.
8. (e) A category is a rank or level in the hierarchical classification of organisms. Taxon is a unit in classification which may represent any level of grouping of organisms based on certain common characteristics. There is some confusion in the use of taxon and category, for example Bryophyta is a taxon while division is a category.
9. (b) The hierarchy includes seven obligate categories – kingdom, division or phylum, class, order, family, genus and species. In order to make taxonomic position of species more precise, certain categories have been added to this list. They are called intermediate categories, e.g., subkingdom, superphylum or superdivision, superclass, subclass, superorder, suborder, superfamily, subfamily, tribe, subspecies, variety etc.
10. (b) The species is genetically distinct and reproductively isolated natural population. Sexual reproduction is absent in prokaryotes and some protists. In such cases morphological differences, cytotaxonomy and chemotaxonomy are resorted to.
11. (b) Bacteria, Protista are single-celled organisms. They do not have circulatory systems and live in moist and watery environments so that all their cells are close enough to the external environments for the direct exchange of substances such as water and gases.
12. (b) All living organisms have definite shape and size and all show specific individuality with a orderly mannered organization whereas at the lower level of organization, both the living and non living made up of atoms

### Critical Thinking Questions

1. (b) Karyotaxonomy is based up on nucleus and band on chromosomes.
3. (a) Hutchinson's systems of classification (1884-1972) are the best known phylogenetic system. It was revised in 1995.
4. (a) Currently 1.7 million living organisms are known to science. Out of these 1.2 million are animals and about 0.5 million plants.

### Assertion and Reason

1. (b) Phylogeny is the developmental history of a species or a group of species. Species is the basic unit of taxonomy. It is a natural population of individuals or group of population which resemble one another in all essential morphological and reproductive characters so that they are able to interbreed freely and produce fertile offspring.
2. (a) In Whittaker's classification, algae are grouped in three kingdoms – Monera (blue-green algae), Protista (dinoflagellates, diatoms, euglenoids) and Plantae (red algae, brown algae and green algae). Though plant kingdom of Whittaker is often called metaphyta or multicellular plants, the algae included in this kingdom also contain a number of unicellular and colonial forms. The most accepted classification of algae is given by Fritsch. He classified all algae into 11 classes.
3. (b) All the members of a species have similar karyotype (cytotaxonomy) – there is similarity in the number, size, shape and behaviour of chromosomes. At the molecular level there is similarity in the types of proteins, enzymes, hormones and other biochemicals.

## The Living World

## Self Evaluation Test

1. When generic name is repeated in specific name of a plant it is called [NCERT]

Or

In fish, *Catla catla* the specific name is identical with the generic name, thus it is an example of

[AMU (Med.) 2012; WB-JEE 2016]

- (a) Synonyms (b) Antonyms  
(c) Tautonyms (d) None of the above
2. Specimen used for original publication by the author is [AIIMS 1996]
- (a) Holotype (b) Isotype  
(c) Syntype (d) Lactotype
3. Number of criteria used in classifying organisms in five-kingdom classification is [NCERT; MP PMT 2001]
- (a) 5 (b) 4  
(c) 3 (d) 2
4. Artificial system of classification was first used by
- (a) Linnaeus (b) De Candolle  
(c) Theophrastus (d) Bentham and Hooker
5. Archegoniatae include
- (a) Algae, fungi and viruses  
(b) Algae, lichens and bryophytes  
(c) Bryophytes, pteridophytes and gymnosperms  
(d) Pteridophytes, gymnosperms and angiosperms
6. Institution which encourages publication of local flora is [APMEE 2001]
- (a) NBRI (b) FRI  
(c) BSI (d) IARI
7. "Taxonomy without phylogeny is similar to bones without flesh" is the statement of
- (a) Oswald Tippo (b) John Hutchinson  
(c) Takhtajan (d) Bentham and Hooker
8. The scientist who created the group Protista for both unicellular plants and animals is
- (a) Haeckel (b) Pasteur  
(c) Lister (d) Koch
9. In a scientific name, the name of author is printed in
- (a) Italics (b) Bold (antics)  
(c) Roman (d) Capital letters

10. The generic name of Mango is [MP PMT 2011]

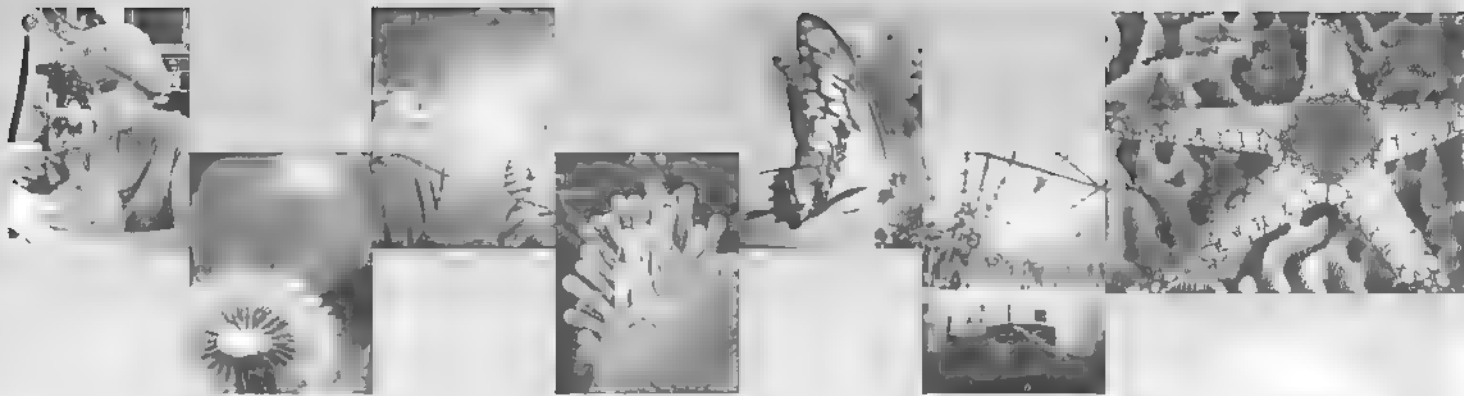
(a) *Mangifera indica* (b) *Indica*  
(c) *Mangifera* (d) *Indica Mangifera*

11. Static concept of species was put forward by
- (a) De Candolle (b) Linnaeus  
(c) Theophrastus (d) Darwin

## Answers and Solutions

1	c	2	a	3	a	4	c	5	c
6	c	7	c	8	a	9	c	10	c
11	b								

1. (c) If both generic and specific names are same, these are called tautonyms.
2. (a) Holotype is a original type specimen from which the description of a species is established
3. (a) The main criteria for classifying organisms into five kingdoms are complexity of cell structure, body organisation, the mode of nutrition, life style and the phylogenetic relationships.
4. (c) Artificial system of classification was first used by Theophrastus. A classification based on one or a few superficial similarities is called an artificial system of classification.
5. (c) Archegoniatae is a group of embryophytes having archegonia. Its include bryophytes, pteridophytes and gymnosperm.
6. (c) Botanical Survey of India at Kolkata explores the plant wealth of India.
8. (a) A German biologist Ernst Haeckel created a third kingdom protista in 1866 for unicellular organism such as bacteria, protozoans, algae and fungi.
9. (c) In a scientific name, the name of author is printed in Roman. e.g., *Mangifera indica* linn, the linn. stand for Linnaeus.
11. (b) The static concept of species was given by Linnaeus in *systema naturae*.



## Chapter 1.2

# Monera (Prokaryotes)

### Characteristics of Monera

Monera (*Monos* – single) includes prokaryotes and shows the following characters .

- (1) They are typically unicellular organisms (but one group is mycelial).
- (2) The genetic material is naked circular DNA, not enclosed by nuclear envelope.
- (3) Ribosomes and simple chromatophores are the only subcellular organelles in the cytoplasm. The ribosomes are 70 S. Mitochondria, plastids, golgi apparatus, lysosomes, endoplasmic reticulum, centrosome, etc., are lacking.
- (4) Sap vacuoles do not occur. Instead, gas vacuole may be present.
- (5) The predominant mode of nutrition is absorptive but some groups are photosynthetic (holophytic) and chemosynthetic.
- (6) The organisms are non-motile or move by beating of simple flagella or by gliding.
- (7) Flagella, if present, are composed of many intertwined chains of a protein **flagellin**. They are not enclosed by any membrane and grow at the tip.
- (8) Moneran cells are microscopic (1 to few microns in length).
- (9) Most organisms bear a rigid cell wall (Peptidoglycan).
- (10) Reproduction is primarily asexual by binary fission or budding. Mitotic apparatus is not formed during cell division.
- (11) The kingdom Monera includes true bacteria, mycoplasma, rickettsias, actinomycetes (ray fungi) etc. Microbiologists also include blue green algae (i.e., Cyanobacteria) under the group of bacteria because of the presence of prokaryotic cell structure. Studies have established that the members of archaeobacteria group are the most primitive and have separated from eubacteria group very early in the process of evolution.

### Bacteria

Study of bacteria is called bacteriology. *Linnaeus* placed them under genus vermes. *Nageli* classified bacteria under schizomycetes. Bacteria are unicellular, microscopic and cosmopolitan organisms. The branch of science, which deals with the study of microorganism and their process is called as microbiology. **Antony Van Leeuwenhoek** is known as father of bacteriology and father of modern microbiology is **Robert Koch**.

These are the smallest cell wall having prokaryotic cell. The bacteria constitute a highly specialised group of one celled plants. They differ from animals in having a rigid cell wall and being capable to synthesize vitamins. Bacteria were first seen by a Dutch lens maker, Antony Van Leeuwenhoek (1683) who named them **animalcules**. *Louis Pasteur* (1822-95) made a detailed study of bacteria and proposed *germ theory of disease*. *Ehrenberg* (1829) was the first to use the term **bacterium**. *Robert Koch* (1881) found that some diseases like tuberculosis, cholera in man, and anthrax in cattle is caused by bacteria. *Lister* introduced antiseptic surgery. He used carbolic acid for sterilization of surgical instrument. Pasteurization theory was proposed by *Louis Pasteur*.

(1) **Size** : They are 3 to 5 microns ( $1\mu = 1/1000$  millimetre or about  $1/25,000$  inch) in length. A few species of bacteria are approximately  $15\mu$  in diameter.

□ Smallest known bacterium is *Dialister pneumonsintes* ( $0.15-0.3\mu$ ).

□ Largest known bacterium is a recently discovered bacterium *thiomargarita namibiensis* (earlier *Bacillus buschili* in cockroach and *Spirillum volutans* were considered to be the largest bacteria).

(2) **Shape** : The bacteria possess the following forms :

**Cocci (Gk. Kokkos = Berry)** : They are oval or spherical in shape. They are called micrococcus when occur singly as in *Micrococcus*, diplococcus when found in pairs as in *Diplococcus pneumoniae*, tetrads in fours, streptococcus when found in chains as in *Streptococcus lactis*, staphylococcus when occurring in grape like clusters as in *Staphylococcus aureus* and *Sarcina*, when found in cubical packets of 8 or 64 as in *Sarcina*.

**Bacilli** : They are rod-shaped bacteria with or without flagella. They may occur singly (bacillus), in pairs (diplobacillus) or in chain (*streptobacillus*).

**Vibrios** : These are small and 'comma or kidney' like. They have a flagellum at one end and are motile, vibrio bacteria has curve in its cell e.g., *Vibrio cholerae*.

**Spirillum (Spira = Coil)** : They are spiral or coiled like a cork-screw. The spirillar forms are usually rigid and bear two or more flagella at one or both the ends e.g., *Spirillum*, *Spirochaetes* etc.

**Filament** : The body of bacterium is filamentous like a fungal mycelia. The filaments are very small e.g., *Beggiatoa*, *Thiothrix* etc.

**Stalked** : The body of bacterium possesses a stalk e.g., *Caulobacter*.

**Budded** : The body of bacterium is swollen at places e.g., *Rhodocyclidium*.

(3) **Flagellation** : Depending upon the presence or absence of flagella, the bacteria are of following types :

**Atrichous** : When the flagellum is absent it is called atrichous. e.g., *Pasteurella pestis*, *Lactobacillus*.

**Monotrichous** : Only one flagellum is found at one end. e.g., *Vibrio cholerae*.

**Lophotrichous** : When a group of flagella is present at one end e.g., *Spirillum volutans*.

**Amphitrichous** : When single or group of flagella is present at both the end e.g., *Nitrosomonas*.

**Peritrichous** : A number of flagella are present all over the body. e.g., *E. coli*, *Clostridium tetani*.

## Staining of bacteria

(1) **Simple staining** : The coloration of bacteria by applying a single solution of stain to a fixed smear is termed simple staining. The cells usually stain uniformly.

(2) **Gram staining** : This technique was introduced by Hans Christian Gram in 1884. It is a specific technique which is used to classify bacteria into two groups Gram +ve and Gram -ve. The bacteria are stained with weakly alkaline solution of crystal violet. The stained slide of bacteria is then treated with 0.5 percent iodine

solution. This is followed by washing with water or acetone or 95% ethyl alcohol. The bacteria which retain the purple stain are called as Gram +ve. Those which become decolourised are called as Gram -ve. In general the wall of Gram +ve bacteria have simpler nature as compared to Gram -ve bacteria. *E.coli* is a Gram -ve bacterium. Gram negative bacterium can be seen with other stain safranin

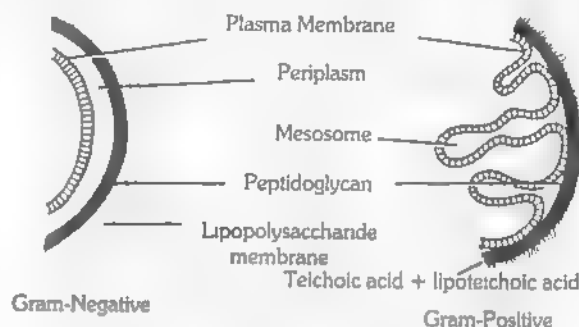


Fig : 1.2-1 Difference between cell walls of Gram-negative and Gram-positive bacteria

**Gram positive bacteria** : e.g., *Pneumococcus*, *Streptococcus*, *Staphylococcus*, *Bacillus*, *Clostridium*, *Mycobacterium*, *Streptomyces*.

**Gram negative bacteria** : e.g., *Salmonella*, *Pseudomonas*, *Escherichia*, *Haemophilus*, *Helicobacter*, *Vibrio*, *Rhizobium*.

Table : 1.2-1

Gram + Positive	Gram - Negative
Cell wall thick (250 – 300 Å).	Cell wall thin (100 – 150 Å)
Cell wall homogenous	Cell wall heterogenous.
Cell wall single layered.	Cell wall 3-layered.
Cell wall more rigid.	Cell wall less rigid
Cell wall made up of mucopeptide (80%).	Cell wall made up of lipoprotein, mucopeptide and lipopolysaccharide
Teichoic acid (5 – 10%) present.	Teichoic acid absent
Spore producing forms included.	No spore producing form.
Polar flagellum usually absent.	Polar flagellum usually present.
Contain Mg-ribonucleate.	Mg-ribonucleate absent.
May produce exotoxins.	May produce endotoxins.
Sensitive to penicillin.	Not sensitive to penicillin
L-lysine present in peptide	Diamino palmitic acid present in peptide.
O-antigen absent	O-antigen present

## Structure of bacteria

(1) **Capsule** : In a large number of bacteria, a slimy capsule is present outside the cell wall. It is composed of polysaccharides and the nitrogenous substances (amino acids) are also present in addition. This slime layer becomes thick, called capsule. The bacteria, which form a capsule, are called capsulated or virulent bacteria. The capsule is usually found in parasitic forms e.g., *Bacillus anthracis*, *Diplococcus pneumoniae*, *Mycobacterium tuberculosis*.

(2) **Cell wall** : All bacterial cells are covered by a strong, rigid cell wall. Therefore, they are classified under plants. Inner to the capsule cell wall is present. It is made up of polysaccharides, proteins and lipids

In the cell wall of bacteria there are two important sugar derivatives are found i.e., NAG and NAM (N-acetyl glucosamine and N-acetyl muramic acid) and besides L or D - alanine, D-glutamic acid and diaminopimelic acid are also found.

One of the unique components of cell wall of bacteria is peptidoglycan or mucopeptide or murein (made of mucopolysaccharide + polypeptide)

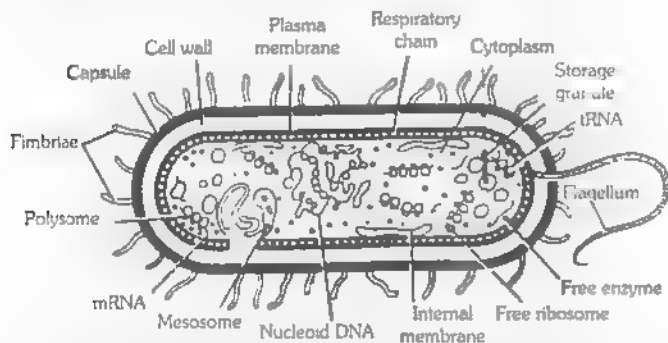


Fig : 1.2-2 Electron microscope structure of a bacterium cell

(3) **Plasma membrane** : Each bacterial cell has plasma membrane situated just internal to the cell wall. It is a thin, elastic and differentially or selectively permeable membrane. It is composed of large amounts of phospholipids, proteins and some amounts of polysaccharides but lacks sterols. It is characterised by possessing respiratory enzymes.

**Mesosome** : On the plasma membrane generally at mid point, there are present some circular coiled bodies called mesosomes. So mesosomes are simply infoldings of plasma membrane. Mesosomes contain respiratory enzymes like oxidases and dehydrogenases and hence they help in respiration. Hence mesosomes are also known as "mitochondria of bacterial cell" or chondrioides. Mesosomes are more prominent in Gram +ve bacteria.

□ It receive DNA during conjugation and DNA replication enzyme.

□ Mesosome participate in the formation of septa during cell division.

(4) **Cytoplasm and Cytoplasmic inclusions** : The cytoplasm is a complex aqueous fluid or semifluid ground substance (matrix) consisting of carbohydrates, soluble proteins, enzymes, co-enzymes, vitamins, lipids, mineral salts and nucleic acids. The organic matter is in the colloidal state.

The cytoplasm is granular due to presence of a large number of ribosomes. Ribosomes (70S) in bacteria are found in the form of polyribosome. Membranous organelles such as mitochondria, endoplasmic reticulum, golgi bodies, lysosomes and vacuoles are absent.

**Volutin granules** : They were first reported in *Spirillum volutans* bacteria. These are also known as metachromatic granules, which are composed of polyphosphate. Volutin serves as a reserve source of phosphate.

**Poly- $\beta$ -hydroxy butyric acid granules (PHB)** : These are polymer of lipid like material and chloroform soluble which are often found in aerobic bacteria especially under high carbon low nitrogen culture conditions. Granules can serve as a reserve carbon and energy source.

**Glycogen and Sulphur granules** : Glycogen are also known as polysaccharide granules. It can be stained brown with iodine. By electron microscopy they appear as dark granules.

(5) **Nucleoid** : It is also known as genophore, naked nucleus, incipient nucleus. There is present nuclear material DNA which is double helical and circular. It is surrounded by some typical protein (polyamine) but not histone proteins.

(6) **Plasmid** : In addition to the normal DNA chromosomes many bacteria (e.g., *E.coli*) have extra chromosomal genetic elements or DNA. These elements are called plasmids. Plasmids are small circular double stranded DNA molecules. The plasmid DNA replicates independently maintains independent identity and may carry some important genes. Plasmid term was given by Lederberg (1952). Some plasmids are integrating into the bacterial DNA chromosome called episomes.

#### Types of plasmid

(i) **F-factor or Fertility factor** : Which is responsible for transfer of genetic material.

(ii) **R-factor or resistance factor** : It provides resistance against drugs.

(iii) **Colicinogenic factor** : Which produces 'Colicines' which kill other bacteria (other than which produce these colicines).

(7) **Flagella** : These are fine, thread-like, protoplasmic appendages which extend through the cell wall and the slime layer of the flagellated bacterial cells. These help in bacteria to swim about in the liquid medium.

The diameter of each subunit is about 40-50Å. These subunits are arranged around a hollow axis. A flagellum is usually 4.5 $\mu$  long and 120-185Å in diameter. Flagellum is attached to cell membrane by a special terminal hook, which is attached to the basal body called (blepharoplast). A bacterial flagellum can be divided into three parts – (Basal granule, Hook and Filament)

(8) **Pili or Fimbriae** : Besides flagella, some tiny or small hair-like outgrowths are present on bacterial cell surface. These are called pili and are made up of pilin protein. They measure about 0.5-2 $\mu$ m in length and 3-5 $\mu$ m in diameter. These are of 8 types I, II, III, IV, V, VI, VII, and F types. I to F are called sex pili. These are present in all most all gram -ve bacteria and few gram +ve bacteria. Fimbriae take part in attachment like holding the bacteria to solid surfaces.

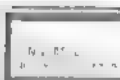
### Reproduction in bacteria

#### Vegetative reproduction

(1) **By budding** : According to Bisset and Hale, reproduction by budding takes place in *Bigidi bacterium bifidus*

(2) **By binary fission** : This type of reproduction is most common in all kinds of bacteria. Under favourable conditions bacterial cell expands. Cytoplasm divides into two parts due to constriction and formation of a transverse septum in the centre of the cell. Later on, these two parts separate from each other and give rise to two cells.





### Asexual reproduction

(1) **By endospores** : Endospores are formed in all species of the genera *Bacillus* and *Clostridium*. In each cell only one endospore is formed. Endospore is highly resistant to very high and very low temperature.

Endospore is found either in the centre or near the cell wall. Under unfavourable conditions cytoplasm shrinks and gets rounded and around it a hard protective three layer is formed. Each endospore may be either circular, ellipsoidal or semicircular. When favourable conditions come, outer layers rupture and active bacterial cell comes out. So this is a method of perennation (i.e., to tide over unfavourable condition) and some people say it "reproduction without multiplication".

(2) **By conidia** : Some filamentous bacteria e.g., *Streptomyces* reproduce by means of conidia. The conidia are spore like in structure and are formed in chains. Each conidium gives rise to a new bacterium.

(3) **By zoospores** : In rare cases bacterial cell forms some motile spores which give rise to new cells. This process has been rarely seen. e.g., *Rhizobium*

### Sexual reproduction (Genetic recombination)

Sometimes it was believed that sexual reproduction does not take place in bacteria. Lederberg and Tatum (1946) proved that sexual reproduction takes place in bacteria. On the basis of this discovery they were awarded Nobel Prize.

According to the present view, three types of sexual reproduction are found in bacteria.

(1) **Transformation** : In this process one kind of bacterium is transformed into another kind. It takes place by transferring DNA from capsulated to non-capsulated bacterium. For the first time Griffith (1928) reported transformation in mice. Later on, Avery, McCleod and McCarty (1944) studied transformation in *Diplococcus pneumoniae*.

(2) **Transduction** : In this process DNA of a bacterial cell is transferred into another bacterial cell through bacteriophage – a kind of virus which is parasitic upon bacteria. Bacteriophage consists of DNA. It has been now accepted that DNA of a bacterial cell is transferred through bacteriophage to another bacterium. Transduction was first of all reported by N.D. Zinder and Lederberg (1952) in bacteria *Salmonella typhimurium*.

(3) **Conjugation** : In this process genetic material from one strain of bacterium which is known as *male* is transferred into another strain of bacterium which is known as *female*. On the experimental basis it is believed that genetic material of male enters into female bacterium in the form of a straight line. Lederberg and Tatum first of all reported conjugation in bacterial strain of *E. coli* called *K<sub>12</sub>* (1946). In 1966, Wollman and Jacob described it in details.

In gram negative bacteria, there are two strains,  $F^+$  (with fertility factor and sex pili) and  $F^-$  (without fertility factor and sex pili). These two can come together. Sex pilus of donor cell extrudes a protein that helps it in attaching to the recipient cell. Later on, sex pilus is converted into conjugation tube between the two. The donor or  $F^+$  can transfer its fertility factor or plasmid to recipient cell or  $F^-$  and convert it into donor as well. Sometimes the  $F^+$  plasmid attaches to nucleoid, becomes episome and converts the

donor into HFr (high frequency of recombination 1 : 100). There is a transfer of few genes of nucleoid from HFr to  $F^-$ . HFr quality can also be transferred occasionally ( $HFr \times F^- = F^-$  plus a few genes and a few HFr). The transferred segment is called **exogenote** which 'similar' segment of the recipient bacterium is known as **endogenote**. The recipient bacterium is called **merozygote** or **partial zygote**. Some of the donor genes integrate into recipient genome.

In gram positive bacteria sex pili do not develop. Donor cells produce a protein **adhesion** over their surface for bringing recipient cells in contact with them. In *Streptococcus faecalis*, the recipient cells excrete a small peptide (sex hormone) for inducing clumping. Wall dissolves in the region of contact. Transfer of DNA segment occurs from donor to recipient cell.

### Respiration in bacteria

With respect to oxygen requirement and mode of cellular respiration, bacteria distinctly belong to two broad categories.

#### (1) Aerobic respiration

**Obligate aerobes** : These bacteria grow exclusively in presence of molecular oxygen and fail to survive in its absence, e.g., *Bacillus subtilis*, *Azotobacter*, *Arthrobacter*, *Mycobacterium* etc.

**Facultative anaerobes** : The aerobic bacteria which can also survive in absence of oxygen, e.g., *Aerobacter*, *Klebsiella*, *Pseudomonas*, etc.

#### (2) Anaerobic respiration

**Obligate anaerobes** : These bacteria grow and multiply in the absence of free oxygen. They fail to survive under aerobic conditions, e.g., *Clostridium botulinum*.

**Facultative aerobes** : The anaerobic bacteria which can also survive in presence of oxygen, e.g., *Chlorobium limicola*.

### Mode of nutrition in bacteria

On the basis of mode of nutrition, bacteria are grouped into two broad categories. First is autotrophic and second is heterotrophic bacteria.

**Autotrophic bacteria** : These bacteria are able to synthesize their own food from inorganic substances, as green plants do. Their carbon is derived from carbon dioxide. These are divided into two categories.

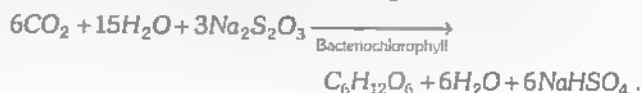
(1) **Photoautotrophic bacteria** : These bacteria are mostly anaerobic bacteria. They use sunlight as source of energy to synthesize food.

They possess a pigment called bacteriochlorophyll which is different from the chlorophyll pigment found in higher plants. This is known as anoxygenic photosynthesis. e.g., **Green sulphur** (*Thiothrix*) and **purple sulphur** (*Chromatium*) bacteria.

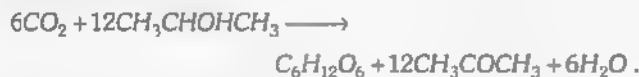
**Green sulphur bacteria** : They are autotrophic. The hydrogen donor is  $H_2S$  and the pigment involved in the process is **chlorobium chlorophyll** (Bacteriochlorophyll) e.g., *Chlorobium*.



**Purple sulphur bacteria** : They are also autotrophic. The hydrogen donor is thiosulphate and the pigment involved in photosynthesis is **bacteriochlorophyll** e.g., *Chromatium*.



**Purple non-sulphur bacteria :** They are heterotrophic utilizing succinate or malate or alcohol. e.g., *Rhodospirillum*, *Rhodopseudomonas*.

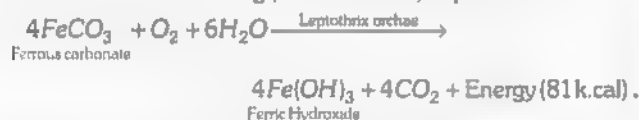


(2) **Chemoautotrophic bacteria :** Some bacteria manufacture organic matter from inorganic raw materials (such as carbon dioxide) and utilize energy liberated by oxidation of inorganic substances present in the external medium such as ammonia, ferrous ion, nitrates, nitrites, molecular hydrogen, etc.

**Sulphur bacteria :** These bacteria derive energy by oxidizing hydrogen sulphide or molecular sulphur. *Beggiatoa*, a colourless sulphur bacterium oxidises hydrogen sulphide ( $\text{H}_2\text{S}$ ) to water and sulphur. The energy released is used up and the sulphur granules are deposited inside or outside the body of bacterial cell



**Iron bacteria :** They take energy from the oxidation of ferrous salts into ferric salts e.g., *Ferrobacillus*, *Leptothrix*.

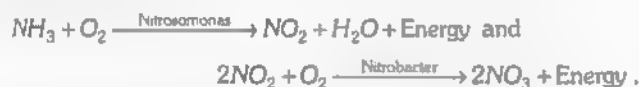


**Hydrogen bacteria :** These bacteria utilize free molecular hydrogen and oxidize to hydrogen into water with the help of either oxygen or oxidize salts e.g., *Hydrogenomonas*.



**Ammonifying bacteria :** They oxidise protein and amino acid into  $\text{NH}_3$  (ammonia). e.g., *Proteus vulgaris*, *Bacillus mycoides*.

**Nitrifying bacteria :** They oxidise ammonia to nitrites and then into nitrates.



**Denitrifying bacteria :** They change nitrogen compound into molecular nitrogen. So that they reduce fertility of soil e.g., *Micrococcus denitrificans*, *Pseudomonas denitrificans*.

**Methane bacteria :** The bacterium *Methanomonas* utilizes methane as source of carbon and energy

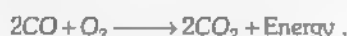


**Methane producing bacteria :** These are spherical or rod shaped bacteria which produce methane ( $\text{CH}_4$ ) from hydrogen gas and carbon dioxide e.g., *Methanobacterium*.



Methane (swamp gas) is produced under anaerobic conditions and can be used as a "biogas", otherwise it is a pollutant that contributes to the green house effect and global warming.

**Carbon bacteria :** These bacteria oxidize carbon monoxide into carbon dioxide and use the liberated energy, e.g., *Bacillus oligocarbophilus*.



(3) **Heterotrophic bacteria :** Most of the bacteria can not synthesize their own organic food. They are dependent on external organic materials and require atleast one organic compound as a source of carbon of their growth and energy. Such bacteria are

called heterotrophic bacteria. Heterotrophic bacteria are of three types – Parasites, Saprotrophs and Symbionts.

(i) **Parasites :** They obtain their organic food or special organic compounds required for their growth from living cells of plants and animals. Some parasitic bacteria are relatively harmless and nonpathogenic, i.e., do not produce disease in hosts.

Table : 1.2-2 Human diseases

Disease	Casual organism
Paratyphoid	<i>Salmonella paratyphi</i>
Gastroenteritis	<i>Salmonella</i> sp. and <i>Escherichia coli</i>
Dysentery	<i>Shigella dysenteriae</i> , <i>S. sonnei</i> , <i>S. boydii</i>
Tularaemia	<i>Francisella tularensis</i>
Influenza	<i>Haemophilus influenzae</i>

Table : 1.2-3 Plant diseases

Disease	Casual organism
Black chaff of wheat	<i>Xanthomonas translucens</i>
Wilt of maize	<i>Xanthomonas stewartii</i>
Gummosis of sugarcane	<i>Xanthomonas asculorum</i>
Red stripe of sugarcane	<i>Pseudomonas rubrilineans</i>
Ring rot of potato	<i>Corynebacterium</i>
Canker of tomato	<i>Corynebacterium michiganense</i>
Leaf spot of Lady's finger	<i>Xanthomonas esculenti</i>
Hairy rot of apple	<i>Agrobacterium rhizogenes</i>
Black knot of grapes	<i>Pseudomonas tumefaciens</i>

(ii) **Saprotrophic bacteria :** These bacteria obtain their nutritional requirements from dead organic matter (such as animal excreta, corpses, fallen leaves, bread, fruits, vegetables, jams, jellies, etc.). These bacteria breakdown the complex organic matter into simple soluble forms by secreting exogenous digestive enzymes. Then they absorb the simple nutrient molecules and assimilate them. Aerobic break down of organic matter is called decomposition or decay. e.g., *Pseudomonas*.

(iii) **Symbiotic bacteria :** Symbiosis is the phenomenon in which the two organisms live in close association in such a way that both the partners get mutual benefit from this association. For example, a very well known nitrogen fixing bacteria – *Rhizobium* forms a symbiotic association with roots of leguminous plants (soyabean, clover, alfalfa, etc.) and producing root nodules.

## Spirochaetes

These are free inhabitants of mud and water, and are chemoheterotrophic unicellular bacteria. These are spiral or helicoid in shape, covered by flexible cell wall and swim actively with flagella present at both pole or ends. Many diseases are caused by them as *Treponema pallidum* causes syphilis, *Leptospira* causes infectious jaundice and *Borrelia* causes relapsing fever. Besides some spirochaetes are found in teeth

## Archaeobacteria

They are present in rumen (first part of stomach) of cattles. This is simplest and most primitive group of bacteria. The cell wall of these bacteria is made of polysaccharides and proteins (peptidoglycans and muramic acid are absent in cell wall). Archaeobacteria are considered to be the 'oldest of living fossils'. Three main groups of archaeobacteria are following.

(1) **Methanogens :** These are strict anaerobic bacteria and mainly occur in muddy areas and also in stomach of cattle, where cellulose is fermented by microbes. These are responsible for

methane gas ( $CH_4$ ) formation in bio-gas plants, because they have capacity to produce  $CH_4$  from  $CO_2$  or formic acid ( $HCOOH$ ). e.g., *Methanobacterium*, *Methanobacillus*, *Methanosarcina* and *Methanococcus*

(2) **Salt lovers archaeobacteria or Halophiles** : These are also anaerobic bacteria, which occur in extreme saline or salty conditions (upto 35% of salt or  $NaCl$  in culture medium). A purple pigmented membrane containing bacteriorhodopsin is developed in sun-light in these bacteria, which utilizes light energy for metabolic activities (different from photosynthesis). e.g., *Holobacterium* and *Halococcus*

(3) **Thermoacidophiles** : These are the bacteria which are found in hot sulphur springs (upto  $80^\circ C$ ). As against first two groups of archaeobacteria, these are aerobic bacteria. These have the capacity to oxidize sulphur to  $H_2SO_4$  at high temperature and high acidity (i.e., pH 2.0), hence given the name *Thermoacidophiles*, i.e., temperature and acid loving.



e.g., *Sulfobolus*, *Thermoplasma*, *Thermoproteus*.

### Actinomycetes (Mycobacteria)

It is a group of unicellular branched filamentous bacteria which resemble fungal mycelia. They grow in the form of radiating colonies in cultures and therefore, commonly called **ray fungi**. They are Gram +ve chemo-organotrophic, saprotrophic bacteria. Most species are facultative anaerobic. These are generally present as decomposers in soil. The filaments are aseptate (non-septate) branched and very thin (about 0.2 to  $1.2 \mu m$  in width). The wall contains mycolic acid. They reproduce asexually by means of conidia, which are produced at tips of filaments. The endospores are not formed. Most of these secrete chemical substances having antimicrobial activities called antibiotics. Some of the most common and effective antibiotics are obtained from the different species of the genus *Streptomyces*.

Table : 1.2-4

(1) Human disease	
Tuberculosis	<i>Mycobacterium tuberculosis</i>
Leprosy	<i>Mycobacterium leprae</i>
Buruli's ulcer	<i>Mycobacterium ulcerans</i>
Actinomycosis	<i>Actinomyces israelii</i>
Diphtheria	<i>Corynebacterium diphtheriae</i>
(2) Animal disease	
Tuberculosis of cattle	<i>Mycobacterium bovis</i>
Lumpy jaw	<i>Actinomyces bovis</i>

### Rickettsias (H.T. Ricketts 1909)

They are gram negative obligate pleomorphic but walled obligate intracellular parasites which are transmissible from arthropods. They are intermediate between true bacteria and viruses. Rickettsias require exogenous factors for growth. Cell wall is like typical bacterial wall. ATP synthesis is absent but ADP is exchanged with host cell ATP. They have genome and size ( $0.3-0.5 \mu m$ ) smaller than true bacteria but have a longer generation time. Internally the cells of rickettsias contain DNA as well as RNA

in a ratio of 1 : 3 : 5. The cell walls contain muramic acid and are sensitive to lysozyme. Flagella, pili and capsule are absent. Reproduction occurs by binary fission. The natural habitat of rickettsias is in the cells of arthropod gut. They cause typhus group of fevers. Spread by droplet method, lice, ticks, fleas, etc.

Table : 1.2-5 Human diseases

Disease	Causal organism
Typhus fever	<i>Rickettsia prowazekii</i>
Rocky mountain spotted fever	<i>Rickettsia rickettsii</i>
Q fever	<i>Coxiella burnetii</i>

### Chlamydiae

(1) They are also called as PLT virus or basophilic virus or energy parasites (as they are not capable of ATP synthesis).

(2) They are pathogenic only to birds and domestic or wild mammals.

(3) They mainly cause keratoconjunctivitis and trachoma (leading to blindness).

### Importance of bacteria

Bacteria are our 'friends and foes' as they have both useful and harmful activities.

#### Useful activities

(1) **In agriculture or In soil fertility** : Some bacteria increase soil fertility. Nitrogen is essential for all plants. Nitrogen occupies 80% of the atmosphere. The plants take nitrogen in the form of nitrates. In soil, nitrates are formed by three processes.

**By nitrogen fixing bacteria** : Bacteria are found in soil either free e.g., *Azotobacter* and *Clostridium* or in root nodules of leguminous plants e.g., *Rhizobium leguminosarum*. These bacteria are capable of converting atmospheric free nitrogen into nitrogenous compounds.

**Nitrifying bacteria** : These bacteria convert nitrogen of ammonia into nitrite ( $NO_2$ ) e.g., *Nitrosomonas* and convert nitrite compounds into nitrates e.g., *Nitrobacter*.

**Decay of dead plants and animals** : Some bacteria attack on dead bodies of plants and animals and convert their complex compounds into simpler substances e.g., carbon dioxide ( $CO_2$ ), water ( $H_2O$ ), nitrate ( $NO_3$ ), sulphate ( $SO_4$ ) etc.

(2) **In dairy** : *Bacterium lactici acidii* and *B. acidii lactici* are found in milk. These bacteria ferment lactose sugar found in milk to form lactic acid by which milk becomes sour.

Lactic acid bacteria bring together droplets of casein a protein found in milk and help in the formation of curd.

**Pasteurization** : Milk is heated at  $62.8^\circ C$  for 30 min or  $71.7^\circ C$  for 15 sec. only. This reduces the number of bacteria by killing all non spore forming bacteria and thus unboiled milk becomes sour earlier than boiled milk.

(3) **In industries** : From industrial point of view bacteria are most important. Some of the uses of bacteria in industries are as follows :

**Vinegar industry** : Vinegar is manufactured from sugar solution in the presence of *Acetobacter aceti*.

## 32 Monera (Prokaryotes)

**Fibre retting :** By this process fibres of jute, hemp and flax are prepared. In the preparation of flax, hemp and jute the retting of stems of *Linum usitatissimum* (Flax = Hindi Sunn), *Cannabis sativa* (Hemp = Hindi Patson) and *Corchorus capsularis* (Jute) respectively is done.

**Tobacco industry :** *Bacillus megatherium* is used for its fermentative capacity for developing flavour and taste in tobacco leaves.

**Tea industry :** By fermentative action of *Mycococcus condisans* curing of tea leaves is done. By this process special taste is developed in the tea leaves.

**Tanning of leather :** Some bacteria decompose fats which are found in skin of animal with the result that skin and hairs are separated from each other and this leather becomes ready for use.

(4) **In medicines :** Some of the antibiotics are manufactured by bacterial actions e.g., *Bacillus brevis* – antibiotic thyrothricin and *B. subtilis* – antibiotic subtilin. Vitamin B<sub>2</sub> is manufactured by fermentative action of *Clostridium acetobutylicum*.

**Antibiotics :** These are the chemical substances produced by living microorganisms capable of inhibiting or destroying other microbes. These are the products of secondary and minor metabolic pathways, mostly secreted extracellularly by the microorganisms. These are used in controlling various infectious diseases.

Table : 1.2-6

Antibiotic	Obtained from
Streptomycin	<i>Streptomyces griseus</i>
Actidine	<i>S. griseus</i>
Chloromycetin	<i>S. venezuelae</i>
Tetracycline	<i>S. aureofaciens</i>
Terramycin	<i>S. rimosus</i>
Erythromycin	<i>S. erythraeus</i>
Neomycin	<i>S. fradiae</i>
Amphotycin	<i>S. carus</i>
Trichomycin	<i>S. hachijoensis</i>
Viomycin	<i>S. floridae</i>
Bacitracin	<i>Bacillus subtilis</i>
Gramicidin	<i>B. brevis</i>
Tyrothricin	<i>B. brevis</i>
Polymyxin	<i>Bacillus polymyxa</i>

(5) **Role of bacteria in petroleum pollution :** Petroleum pollution in water bodies is checked upto some extent by *Pseudomonas*

Genetically engineered strain of *Pseudomonas putida* (superbug) was developed by Dr. Ananda Mohan Chakraborty which biodegrade spilled oil. These superbugs were allowed by USA government in 1990 for removal of oil from water

### Harmful activities

(1) **Cotton spoilage :** It is done by bacteria called *Spirochaete cytophage*.

(2) **Food poisoning :** Some saprotrophic bacteria cause decay of our food, i.e., they alter their normal form and induce unpleasant aroma, taste and appearance. Some bacteria produce powerful toxins in food to cause "food poisoning". Consumption of such food may cause serious illness or even death.

**Botulism :** It is caused by *Clostridium botulinum*. The main symptoms are vomiting followed by paralysis and death.

(3) **Spoilage of food :** Some examples of bacterial food spoilage are :

Greening on meat surface is caused by *Lactobacillus* and *Leuconostoc*. Souring of milk is caused by *Lactobacillus* and *Streptococcus*. Explosion of curd (gas production) is caused by *Clostridium* and *Coliform* bacteria. Ropiness (i.e., slimy milk) is caused by *Klebsiella* and *Enterobacter* sp.

(4) **Pollution of water :** There are reports of epidemics of cholera, typhoid, jaundice and other infectious diseases, which were caused by polluted water. Many pathogenic bacteria such as, *Vibrio cholerae*, *Salmonella typhi*, *Leptospira ceterohaemorrhagiae*, etc. pollute water and make it unfit for drinking. These are eliminated by chlorination.

(5) **Deterioration of textiles :** Some bacteria (e.g., *Cytophaga*, *Vibrio* and *Cellulomonas*) damage cellulose of textiles.

(6) **Abortion :** Bacteria like *Salmonella* induce abortion in goats, horses, sheep etc.

(7) **Biological warfare :** Some bacteria which cause diseases like anthrax, black-leg, tuberculosis etc, are employed as secret war agents.

(8) **Denitrification :** Denitrification bacteria like *Bacillus licheniformis*, *Pseudomonas aeruginosa* convert nitrates and nitrites into free nitrogen, thus responsible for the process of denitrification. Thus soil is depleted of essential nutrient like usable form of nitrogen.

(9) **Putrefaction :** It is the spoilage of protein in the absence of O<sub>2</sub> by the putrefying bacteria e.g., *Proteus*, *Mycoides*.

(10) **Retting of fibres :** It is the hydrolysis of pectic substances that bind the cells together. e.g., *Clostridium* sp., *Pseudomonas fluorescence*.

## Mycoplasma

Mycoplasmas were discovered by **E. Nocard** and **E. R Roux** (1898). They were first isolated from bovine sheep suffering from pleuropneumonia. They are often designated as pleuropneumonia-like organisms (PPLO). These organisms were later put under the generic name mycoplasma by Nowak (1929). In 1966 international committee of nomenclature of bacteria, placed mycoplasmas under the class *Mollicutes*, which consists of two genera *Mycoplasma* and *Acholeplasma*.

**Structure :** These are the simplest and smallest unicellular non-motile known aerobic prokaryotes without cell wall. So that they can change their shape therefore called Jockers of microbiological park. Their size varies from 0.1 – 0.15  $\mu$ m. Due to the absence of the cell wall, these organisms are highly elastic and readily change their shape; hence the mycoplasmas are irregular and quite variable in shape. That is called pleomorphism. Mycoplasma cells are covered with three layered plasma membrane.

Unit membrane is made up of lipoprotein. The genetic material is a single, linear, double-stranded molecule of DNA, without a nuclear envelope. Unlike other prokaryotes, it is coiled throughout the cytoplasm. The cytoplasm contains the ribosomes which are 70S. It also contains RNA, proteins, lipids and many kinds of enzymes used in biosynthetic reactions. Mycoplasmas are gram-negative.

**Physiology and reproduction :** Mycoplasma are usually non-motile. They are sensitive to tetracycline and resistant to penicillin. These are destroyed usually by treatment of heat at 50° C for 6 hours mycoplasma are osmotically inactive. Mycoplasmas are heterotrophic in their mode of nutrition. Some of them are saprotrophs, but most of them are parasitic on plants and animals including man. They reproduce by budding or binary fission. Fragmentation specially in filamentous forms. Besides this, Mycoplasma reproduces by elementary cell bodies also. It is also called bleb particle. It is a kind of vegetative reproduction.

### Importance of Mycoplasma

(1) **Diseases in human beings :** *Mycoplasma hominis* causes pleuropneumonia, inflammation of genitals and endocarditis, etc. *Mycoplasma pneumoniae* causes primary atypical pneumonia (PAP), haemorrhagic laryngitis, etc. *Mycoplasma fermentatus* and *M. hominis* cause infertility in man, otitis media (inflammation of middle ear).

(2) **Diseases in animals :** *Mycoplasma mycoides* causes pneumonia in cattle. *Mycoplasma bovis* causes inflammation of genitals in animals. *Mycoplasma agalactia* causes agalactia of sheep and goat.

(3) **Diseases in plants :** Common mycoplasmal diseases of plants are: Bunchy top of papaya, witches' broom of legumes, yellow dwarf of tobacco, stripe disease of sugarcane, little leaf of brinjal, clover phyllody, big bud of tomato etc.

### Cyanobacteria

The new name of cyanobacteria has been given to myxophyceae or cyanophyceae. Cyanobacteria form a group of ancient Gram negative, photosynthetic prokaryotes. Many botanists prefer to call them blue-green algae. They have survived successfully for about 3 billion years. They may cause water blooms.

Cyanobacteria are predominantly fresh water forms, a few are marine. They impart unpleasant taste and smell to the water. One species of cyanobacteria containing red pigment (*Trichodesmium erythraeum*) flourishes in red sea and is responsible for the red colour of its water.

#### Characteristics of Cyanobacteria

- (1) They have prokaryotic type of cells.
- (2) Cells do not have any organised nucleus. The nucleolus is absent and the nucleoid is not to be bounded by a nuclear membrane. The type of nucleus called **incipient nucleus**.
- (3) The photosynthetic pigments present in the cell are – chlorophyll *a*,  $\beta$  carotene, myxoxanthophyll, myxoxanthin, C-phycoerythrin and C-phyocyanin. The C-phyocyanin is blue and C-phycoerythrin is red in colour. If C-phyocyanin is more as compared to C-phycoerythrin, it gives characteristic blue-green colour to the algae.
- (4) The photosynthetic pigment are present in lamellae, called thylakoids
- (5) The presence of chlorophyll-*a*, cyanobacteria synthesis their own food from carbon dioxide and water in the presence of

sunlight. Certain cyanobacteria fix atmospheric nitrogen in the presence of oxygen.

(6) In cyanobacteria food is stored as cyanophycean starch or  $\alpha$ -granules.

(7) Some members possess simple unbranched filament with heterocyst like *Nostoc*, *Anabaena*, *Aulosira*, *Cylindrospermum* etc.

(8) Some members possess simple unbranched filamentous forms without heterocysts and akinetes, e.g., *Arthospira*, *Oscillatoria*, *Spirulina*, *Phormidium*, *Lyngbya*, *Symploca*, *Microcoleus*, *Schizothrix* etc.

(9) Cyanobacteria reproduce asexually by fission and fragmentation. Unicellular forms multiply by binary fission. Sexual reproduction is totally absent.

(10) Cell wall is composed of a gelatinous sheath which is made up of three layers of microfibrils in which cellulose is not present.

(11) Cells contain organelles like cyanophycean granules, gas vacuoles, polyhedral bodies, ribosomes, polyglucoside bodies, polyphosphate bodies etc.

(12) Cyanobacteria are economically important because of having immense capability of fixing atmospheric nitrogen in the soil. An enzyme nitrogenase present in the heterocyst is responsible for the fixation of free nitrogen. Application of heterocysts blue-green algae as biofertilizer enhances the production in paddy field crops. e.g., *Anabaena*, *Nostoc*, *Cylindrospermum*, *Scytonema* etc.

### Economic importance of Cyanobacteria

Cyanobacteria have both beneficial and harmful effects in human affairs.

#### Useful activities

- (1) Growth of cyanobacteria in hard water is most probably responsible for the deposit of limestones.
- (2) Since they grow, photosynthesis, multiply and ultimately die, thus adding organic matter to the soil and increasing its fertility.
- (3) Whereas some cyanobacteria act to breakdown rock, the species that live in hot springs actually build rocks. This they accomplish by depositing salts of calcium and silica within the gelatinous sheath of the algal cell wall.
- (4) Balls of *Nostoc commune* are collected, boiled and consumed as food by the Chinese and South Americans. The prepared food is called 'Yoyucho'.
- (5) Some cyanobacteria, such as *Anabaena*, *Lyngbya* etc. help in conservation of soil, thus checking soil erosion.

(6) Few species of *Anabaena* and *Aulosira* are inoculated in ponds to check the development of mosquito larvae.

(7) *Spirulina* is cultivated in tanks to obtain protein rich animal food as well protein rich health food.

#### Harmful activities

- (1) Their most harmful effect is undoubtedly the formation of blooms in bodies of water.
- (2) They choke the intake of water supply systems and give the water a disagreeable odour giving a fishy taste to drinking water.
- (3) Many cyanobacteria produce toxins. They are directly or indirectly harmful for human. e.g., *Nostoc*, *Anabaena*, *Microcystis* etc.

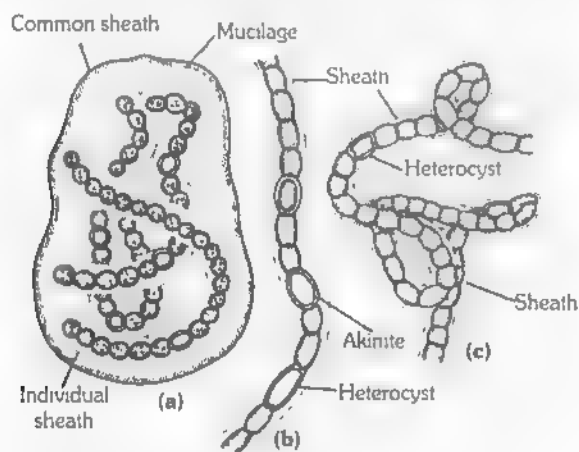
**Nostoc**

**Habitat :** *Nostoc* is found in aquatic and terrestrial habitat. The alga forms a jelly like mass in which numerous filaments are embedded. When young, they are more or less spherical, solid and microscopic in size. With advance in age, the colony grows and becomes macroscopic. In species like *N. amplissimum* it attains the diameter of 30cm or almost equals to the size of hen's egg in *N. punctiforme*. A number of species of *Nostoc* on soil. They often swell up and glisten after rains and therefore called fallen stars.

**Morphology :** The plant is filamentous and trichome are unbranched and appear moniliform..

All the cells of the trichome are similar in structure but at intervals are found slightly larger rounded, light yellowish, thick walled cells called as *heterocysts*. Trichome mostly breaks near heterocyst and forms hormogonia and thus they help in its multiplication.

Each cell trichome in *Nostoc* has primitive nucleus and chromoplasm and very much resembles in all details to a cyanophycean cell. Vacuoles and definite chromatophores are absent. The cell wall is differentiated into two layers. Outside the cell wall there is a mucilaginous sheath. Due to confluence of various mucilaginous sheaths of filaments, a mucilaginous colony is formed. The cell is *prokaryotic*.

Fig : 1.2-3 *Nostoc***Reproduction in Nostoc**

There is no sexual reproduction in *Nostoc* but it reproduces asexually by following methods

(1) **Hormogonia :** The filaments break at number of places into smaller pieces called as hormogonia by death and decay of an ordinary cell. They slip out of the mucilage sheath and grow into new plant. Frequently trichomes break near heterocysts

(2) **Resting spores or akinetes :** Under certain conditions some of the vegetative cells enlarge and accumulate food material and develop thick walls. These are called akinetes and may be arranged on either side of the heterocysts or in between two heterocysts. In mature akinete the outer wall may be 2-3 layered and its protoplasm becomes highly granular. The akinetes germinate after a period of rest and the contents are liberated out through a pore. The protoplast by further division forms the filament.

(3) **Heterocysts :** In exceptional case like *N. commune* the heterocyst may become functional and on germination produces a new colony.

(4) **Endospores :** *Nostoc microscopium* and *Nostoc commune* produce endospore.

**Economic importance**

(1) Many species of *Nostoc* fix atmospheric nitrogen and thus increases soil fertility

(2) Reclamation of alkaline usar soils can be done by employing some species of *Nostoc*.

(3) *N. commune* is consumed as vegetable in China and Japan.

**Tips & Tricks**

- ✚ Pasteurization : Kills all non endospore forming bacteria.
- ✚ Insulin is the first hormone which obtained from genetically engineered bacteria.
- ✚ Free living  $N_2$  fixing bacteria – *Azotobacter* and *Polymyxa*.
- ✚ *Clostridium butyricum* has been used in the synthesis of vitamin B.
- ✚ Commensals : Those microorganism which are living in large intestine of human and that feed on undigested food without harming the host are termed as commensals.
- ✚ External DNA enters in bacteria through mesosomes.
- ✚ In bacteria flagella may be present, PS-II absent, photosynthesis is a nonoxygenic.
- ✚ Flagella of *Salmonella* bacteria contain H-antigens.
- ✚ Chemically *E.coli* has about 70%  $H_2O$ , 15% proteins, 6% RNA, 1% DNA, 2% Lipid, 3% carbohydrates, etc
- ✚ Hay bacteria is *Bacillus subtilis*.
- ✚ Deodorants have salts of Zn and Al which kill bacteria causing odour.
- ✚ Alternation of generations is absent in bacteria due to absence of meiosis and syngamy.

**Ordinary Thinking****Objective Questions****Structure, shape and nutrition of bacteria**

1. Which of the following statement is correct [DUMET 2010]
  - (a) All bacteria are heterotrophic
  - (b) Bacteria are either heterotrophic or chemoautotrophic
  - (c) Bacteria can also be photoautotrophic
  - (d) Bacteria are either photoautotrophic or chemoautotrophic
2. Bacteria were first discovered by [NCERT; CBSE PMT 1995; AFMC 1997; Kerala PMT 2000]
  - (a) Robert Koch
  - (b) L. Pasteur
  - (c) Robert Hooke
  - (d) A.V. Leeuwenhoek



3. On the basis of r-RNA genes bacteria are divided into [Odisha JEE 2008]
- Gram +ve and Gram -ve
  - Bacteria and archaeobacteria
  - Actinomycetes and mycoplasma
  - Cyanobacteria and mycolasma
4. In *Escherichia coli* [CBSE PMT 1993]
- An organised nucleus is present
  - One chromosome is present
  - One DNA molecule is present
  - One RNA molecule is present
5. Which of the following fixes  $CO_2$  in carbohydrates
- Bacillus*
  - Rhizobium*
  - Nitrobacter*
  - Rhodospirillum*
6. Bacteria are considered as plants, because [CPMT 1994; BHU 2005]
- These have a rigid cell wall
  - They have a green colour
  - They can reproduce
  - They are present everywhere
7. Membrane-bound organelles are absent in [CBSE PMT (Pre.) 2010]
- Plasmodium*
  - Saccharomyces*
  - Streptococcus*
  - Chlamydomonas*
8. How many organisms in the list given below are autotrophs *Lactobacillus*, *Nostoc*, *Chara*, *Nitrosomonas*, *Nitrobacter*, *Streptomyces*, *Sacharomyces*, *Trypanosoma*, *Porphyr*, *Wolffia* [NCERT; CBSE PMT (Main) 2012]
- Four
  - Five
  - Six
  - Three
9. Gram -ve and +ve bacteria have cell membrane made up of [RPMT 1997]
- Proteins and lipids
  - Cellulose
  - Fats
  - Chitin
10. Some hyperthermophilic organisms that grow in highly acidic (pH 2) habitats belong to the two groups [CBSE PMT (Pre.) 2010]
- Liverworts and yeasts
  - Eubacteria and archaea
  - Cyanobacteria and diatoms
  - Protists and mosses
11. The chief component of bacterial cell wall is
- Cellulose and chitin
  - Cellulose and pectin
  - Amino acids and polysaccharides
  - Cellulose and carbohydrates
12. Bacteria whose cell has only a curve/comma is [NCERT; EAMCET 1995]
- Vibrio*
  - Cocci*
  - Spirilli*
  - Bacilli*
13. The main difference between Gram positive and Gram negative bacteria lies in the composition of [NCERT; CBSE PMT 2001; Odisha JEE 2009; WB JEE 2011]
- Cilia
  - Cell wall
  - Nucleolus
  - Cytoplasm
14. Muramic acid is present in the cell wall of [Pb. PMT 1999; BHU 2000; KCET 2001; CPMT 2009]
- Bacteria/Blue green algae
  - Green algae
  - Yeast
  - Rhizopus*
15. The shape of the cocci bacteria is [AMU (Med.) 2012]
- Rod shaped
  - Spherical
  - Comma shaped
  - Spiral
16. Match the following pairs correctly and choose the right combination
- | Column-I                         | Column-II                               |
|----------------------------------|---|
| A. <i>Escherichia coli</i>       | 1. 'nif' gene                           |
| B. <i>Rhizobium melilotae</i>    | 2. Digests hydrocarbon of crude oil     |
| C. <i>Bacillus thuringiensis</i> | 3. Production of human insulin          |
| D. <i>Pseudomonas putida</i>     | 4. Biological control of fungal disease |
|                                  | 5. Bio-decomposed insecticide           |
- (a) A = 3, B = 1, C = 5, D = 4  
(b) A = 1, B = 2, C = 3, D = 4  
(c) A = 2, B = 1, C = 3, D = 4  
(d) A = 4, B = 3, C = 1, D = 2  
(e) A = 3, B = 1, C = 5, D = 2
17. Helically coiled shaped bacteria are called [Odisha JEE 2008]
- Spirilla*
  - Cocci*
  - Bacilli*
  - Vibrio*
18. Which of the following is a genetic vector [BVP 2001]
- Phage
  - Plasmid
  - Mosquito
  - None of these
19. Bacteria bearing flagella all over the body are called [CPMT 1999; BHU 2000; MP PMT 2001; MHCET 2003]
- Peritrichous
  - Atrichous
  - Monotrichous
  - Cephalotrichous
20. The habitat of *E. coli* is [NCERT; RPMT 1995; EAMCET 1995; CBSE PMT 1998; Odisha JEE 2008]
- Water
  - Colon (Intestine)
  - Soil
  - Organic food
21. Bacterial ribosomes are called
- Autosomes
  - Dictyosomes
  - Centrosomes
  - Polyribosomes
22. Choose the wrong statements regarding bacterial cell
- Glycocalyx is the outer most envelope in bacteria
  - The glycocalyx could be a loose sheath called capsule
  - The glycocalyx may be thick and tough called slime layer
  - A special structure formed by the plasma membrane is called mesosome
  - Small bristle like fibres sprouting out of the cell are called fimbriae
- (a) A and C are wrong (b) A and B are wrong  
(c) B and C are wrong (d) A and D are wrong  
(e) C and D are wrong

## 36 Monera (Prokaryotes)

23. Which one of the following organisms is not an example of eukaryotic cells [CBSE PMT (Pre.) 2011]
  - (a) *Amoeba proteus* (b) *Paramecium caudatum*
  - (c) *Escherichia coli* (d) *Euglena viridis*
24. Which of the following statement is correct [CPMT 2005]
  - a) *E. coli* gram -ve bacterium while *Rhizobium japonicum* is gram +ve bacterium
  - b) Both *E. coli* and *Rhizobium japonicum* are gram +ve
  - c) Both *E. coli* and *Rhizobium japonicum* are gram -ve
  - d) *E. coli* is gram +ve, *Rhizobium japonicum* is gram -ve
25. Which of the following compounds are decomposed during putrefaction
  - (a) Proteins (b) Fats
  - (c) Carbohydrates (d) None
26. In the light of recent classification of living organisms into three domains of life (bacteria, archaea and eukarya), which one of the following statements is true about archaea [CBSE PMT 2008]
  - (a) Archaea completely differ from both prokaryotes and eukaryotes
  - (b) Archaea completely differ from prokaryotes
  - (c) Archaea resemble eukarya in all respects
  - (d) Archaea have some novel features that are absent in other prokaryotes and eukaryotes
27. Bacteria obtaining energy from oxidation of inorganic substances are called [MP PMT 1999]
  - (a) Chemolithotrophs (b) Photolithotrophs
  - (c) Photo organotrophs (d) Chemo organotrophs
28. Bacterial ribosomes are present
  - (a) In cytoplasm (b) On endoplasmic reticulum
  - (c) On nuclear membrane (d) On cell wall
29. Mesosome in a bacterial cell is [MP PMT 1995, 97, 98; CBSE PMT 1997; MHCET 2001; BHU 2003; AIEEE Pharmacy 2004; Manipal 2005]
  - (a) Plasmid
  - (b) Connection between two cells
  - (c) Plasma membrane infolded for respiration
  - (d) None of these
30. Colourless, unicellular, cell wall bound, spherical or rod-shaped micro-organism and lacking organized nucleus is called [CPMT 2004]
  - (a) Mycoplasma (b) Virus
  - (c) Bacteria (d) Cyanobacteria
31. Bacterial flagella is made up of [AIIMS 2004]
  - (a) Protein (b) Amines
  - (c) Lipids (d) Carbohydrates
32. Which one of the following is not a characteristic of gram positive bacteria [Kerala PMT 2008]
  - (a) Cell wall is smooth
  - (b) Mesosomes are distinctively prominent
  - (c) Basal body of flagellum contains 2 rings
  - (d) Outer membrane is present
  - (e) Murein content of cell wall is 70 – 80%
33. Bacterial flagella do not show ATPase activity and 9 + 2 organization. These are chemically [AFMC 2006]
  - (a) Flagellin (b) Pilin
  - (c) Tubulin (d) Bacterin
34. Plasmids are extra chromosomal genetic material of [KCET 2001; MP PMT 2002; CPMT 2009; Odisha JEE 2011; PET (Pharmacy) 2013]
  - (a) Bacteria (b) Virus
  - (c) Algae (d) Amoeba
35. Which of the following amino acid is present only in bacteria and BGA [MP PMT 2007]
  - (a) Glutamic acid (b) Diaminopimelic acid
  - (c) Glycine (d) Tyrosine
36. Shorter generation time of *E. coli* compared to eukaryotes may be explained on the basis of [WB JEE 2008]
  - (a) Shape
  - (b) large surface: volume ratio
  - (c) Presence of cell wall
  - (d) Absence of organelles
37. Teichoic acid is found in [J & K CET 2008; CPMT 2009; AFMC 2012]
  - (a) Gram (+ve) bacteria (b) Gram (-ve) bacteria
  - (c) Cyanobacteria (d) Mycoplasma
38. N-acetyl muramic acid is found as [WB JEE 2012]
  - (a) Cell wall component of plant
  - (b) Cell wall component of Gram positive bacteria
  - (c) Cell wall component of fungi
  - (d) Viral coat material
39. The nitrifying bacteria are [MP PMT 1994]
  - (a) Autotrophic (b) Saprophytic
  - (c) Parasitic (d) Chemosynthetic
40. Branched chain lipids occur in the cell membranes of
  - (a) *Archaeobacteria* (b) *Mycoplasma*
  - (c) *Actinomycetes* (d) *Streptomyces*
41. Smallest bacteria is [CPMT 2002]
  - (a) *Spirillum* (b) *Bacillus*
  - (c) *Dialister* (d) None of these
42. A mutant micro-organism unable to synthesize a compound required for its growth but able to grow if the compound is provided, is known as [MP PMT 2001]
  - (a) Auxotroph (b) Prototroph
  - (c) Autotroph (d) None of these
43. Which one of the following organisms may respire in the absence of oxygen [MP PMT 2002]
  - (a) *Azotobacter* (b) *Clostridium*
  - (c) *Rhizobium* (d) *Lactobacillus*
44. A bacterium is capable of withstanding extreme heat, dryness and toxic chemicals. This indicates that it is probably able to form [KCET 2009]
  - (a) A thick peptidoglycan wall
  - (b) Endospores
  - (c) Endotoxins
  - (d) Endogenous buds

45. First organism which was evolved on the earth  
[CBSE PMT 2001]  
(a) Saprotrophs (b) Chemoheterotrophs  
(c) Photoautotrophs (d) Chemoautotrophs
46. Antony Van Leeuwenhoek was first discovered bacteria. He belongs to which country  
[MP PMT 2002]  
(a) France (b) Sweden  
(c) Holland (d) United Kingdom
47. Bacteria are included in which of the following kingdoms  
[AFMC 2001]  
(a) Protista (b) Plantae  
(c) Monera (d) Animalia
48. *Salmonella* sp. is  
[MP PMT 2002]  
(a) Monotrichous (b) Lophotrichous  
(c) Amphitrichous (d) Peritrichous
49. Who classified bacteria under Schizomycetes  
[MP PMT 2000]  
(a) Nageli (b) Linnaeus  
(c) Leeuwenhoek (d) Sadashivan
50. The correct sequence of stages of growth curve for bacteria is  
[Pb. PMT 1999; CBSE PMT 1999]  
(a) Decline, lag, log phase  
(b) Lag, log, stationary phase  
(c) Stationary, lag, log, decline phase  
(d) Lag, log, stationary, decline phase
51. Genophore term was coined by Hans Ris for  
[MP PMT 2007]  
(a) Genetic material of virus  
(b) Stack on which spore originated  
(c) Bacterial chromosome  
(d) Fungal chromosome
52. The DNA of *E. coli* is  
[CBSE PMT 1997, 98]  
(a) Single stranded and linear  
(b) Single stranded and circular  
(c) Double stranded and linear  
(d) Double stranded and circular
53. In prokaryotes the Glycocalyx when it is thick is called  
[KCET 2015]  
(a) Capsule (b) Slime layer  
(c) Cell wall (d) Mesosome
54. When a bacterium is provided with flagella arising from two opposite ends, it is called  
[KCET 1998; CPMT 2001, 10; MP PMT 2012]  
(a) Monotrichous (b) Lophotrichous  
(c) Amphitrichous (d) Polytrichous
55. The structure that help some bacteria to attach to rocks and/or host tissues are  
[AIPMT 2015]  
(a) Fimbriae (b) Mesosomes  
(c) Holdfast (d) Rhizoids
56. What is a genophore  
[WB JEE 2011]  
(a) DNA in prokaryotes  
(b) DNA and RNA in prokaryotes  
(c) DNA and protein in prokaryotes  
(d) RNA in prokaryotes
57. An example of iron bacteria is  
[MP PMT 1999]  
(a) *Beggiatoa* (b) *Geobacillus*  
(c) *Ferrobacillus* (d) None of these
58. Bacteria are made up of  
[Bihar MDAT 1995]  
(a) Nucleic acid (b) Only proteins  
(c) Nucleic acid and proteins (d) Nucleosides  
(e) None of these
59. Genes for antibiotic resistance are located in  
[BHU 1995; MP PMT 1995, 98]  
Or  
Bacterial resistance to antibiotics is a genetic trait, it is normally carried by the  
[WB JEE 2016]  
(a) Chromosome (b) Nucleus  
(c) Cell wall (d) Plasmid
60. The cells of bacterium *Staphylococcus* remain arranged in the form of  
[MP PMT 1995, 98; BVP 2002]  
(a) Plate (b) Cube  
(c) Irregular cluster (d) Chain
61. 'Peptidoglycan' is a characteristic constituent of the cell wall of  
[BHU 1994, 2008; MP PMT 1997; AIIMS 1999; Kerala PMT 2006, 07]  
(a) Eubacteria and unicellular eukaryotes  
(b) Bacteria and cyanobacteria  
(c) Archaeobacteria and eukaryotes  
(d) All members of 'monera' and 'protista'
62. Bacteria and other monerans do not possess  
[CPMT 2000]  
(a) Ribosomes (b) Mitochondria  
(c) Nucleoid (d) Plasma membrane
63. Mucopeptide in cell wall is more in  
[MP PMT 1999]  
(a) Gram-positive bacteria (b) Gram-negative bacteria  
(c) Cyanobacteria (d) Bacteriophage
64. Identify the bacterium that appears violet after Gram staining  
[WB JEE 2012]  
(a) *Salmonella enterica*  
(b) *Escherichia coli*  
(c) *Mycobacterium tuberculosis*  
(d) *Rhizobium meliloti*
65. Many bacteria bear minute hairy structures on their cell wall, these are called  
[AFMC 1996]  
(a) Hairs (b) Flagella  
(c) Pili (d) Cilia
66. Which of the following is not correct statement about the plasmids  
[Odisha JEE 2011]  
(a) It is the extra chromosomal DNA in bacteria  
(b) It is not a integral part but inert genetic material  
(c) Host chromosome can be integrated with the plasmid  
(d) Transfer of plasmid can be done from cell to cell without killing the host
67. Infoldings of the plasma membrane of gram positive bacteria, gives rise to  
(a) Clathrin (b) Chondrin  
(c) Chondrioides (d) Chromatin
68. Bacteria with tuft of flagella at one pole is known as  
[Odisha JEE 2012]  
(a) Amphitrichous (b) Peritrichous  
(c) Atrichous (d) Lophotrichous

## 38 Monera (Prokaryotes)

69. Circular DNA molecule occurs in [NCERT; Pb. PMT 1994; MP PMT 1995, 98; CBSE PMT 1996; AIEEE Pharmacy 2003]

(a) Viruses  
(b) Bacteria, chloroplasts and mitochondria  
(c) Bacteria and chloroplasts only  
(d) Bacteria only

70. Extension of plasma membrane in prokaryotes is [DPMT 2007]

(a) ER (b) Mesosome  
(c) Ribosome (d) None of these

71. Bacterial cells can be stained with [MP PMT 1999]

(a) Mercuric chloride (b) Crystal violet  
(c) Crystal violet and iodine (d) Safranin

72. The term 'glycocalyx' is used for [NEET (Karnataka) 2013]

(a) A layer present between cell wall and membrane of bacteria  
(b) Cell wall of bacteria  
(c) Bacterial cell glyco-engineered to possess N-glycosylated proteins  
(d) A layer surrounding the cell wall of bacteria

73. Why is a capsule advantageous to a bacterium [NEET (Karnataka) 2013]

(a) It protects the bacterium from desiccation  
(b) It provides means of locomotion  
(c) It allows bacterium to "hide" from host's immune system  
(d) It allows the bacterium to attach to the surface

74. According to the shapes the names of the different bacteria are given below. Identify them [NCERT]



(a) A - *Spirilla*, B - *Vibrio*, C - *Cocci*, D - *Bacilli*  
(b) A - *Spirilla*, B - *Bacilli*, C - *Cocci*, D - *Vibrio*  
(c) A - *Bacilli*, B - *Cocci*, C - *Spirilla*, D - *Vibrio*  
(d) A - *Cocci*, B - *Bacilli*, C - *Spirilla*, D - *Vibrio*

75. Archaeobacteria differ from eubacteria in [CBSE PMT 2014]

(a) Cell shape (b) Mode of reproduction  
(c) Cell membrane structure (d) Mode of nutrition

76. Which structures perform the function of mitochondria in bacteria [CBSE PMT 2014]

(a) Cell wall (b) Mesosomes  
(c) Nucleoid (d) Ribosomes

77. Which one of the following matching pairs is WRONG [WB JEE 2016]

(a) Bacterial cell wall - cellulose  
(b) Bacterial ribosome - 16S rRNA  
(c) Bacterial flagella - protein  
(d) Bacterial glycocalyx - cellulose

78. Methanogens belong to [NEET (Phase-II) 2016]

(a) Slime moulds (b) Eubacteria  
(c) Archaeobacteria (d) Dinoflagellates

79. Which of the following are found in extreme saline conditions [NEET 2017]

(a) Archaeobacteria (b) Eubacteria  
(c) Cyanobacteria (d) Mycobacteria

80. Which of the following components provides sticky character to the bacterial cell [NEET 2017]

(a) Cell wall (b) Nuclear membrane  
(c) Plasma membrane (d) Glycocalyx

### Life cycle/Reproduction in bacteria

1. Bacterial cell divides in every minute it takes one hour to fill up a cup. How much time will be taken to fill half the cup  
(a) 59 minutes (b) 30 minutes  
(c) 60 minutes (d) 29 minutes

2. Under the optimum condition of temperature and nutrition most of the bacteria divide at the interval  
(a) 24 hours (b) 20 minutes  
(c) 60 minutes (d) 5 minutes

3. Transformation experiments using *Pneumococcus* bacteria led to the hypothesis that [CBSE PMT 1993, 99]

(a) DNA is the genetic material  
(b) Bacteria have sexual reproduction  
(c) Chromosomes are made up of DNA  
(d) RNA is the transfer link

4. The process in which viruses are involved in sexual reproduction of bacteria is called [MP PMT 1996, 2011; CPMT 1999, 2001; BHU 2000, 01, 08; JIPMER 2001; Haryana PMT 2005]

Or

The transfer of genetic material from one bacterial cell to another through a vector is [MH CET 2007]

(a) Transduction (b) Transcription  
(c) Transformation (d) Translation

5. Bacteria commonly reproduce vegetatively by [NCERT; WB JEE 2008]

Or

Which one of the following processes results in the formation of clone of bacteria [KCET 2010]

(a) Binary fission (b) Budding  
(c) Conjugation (d) Oldia

6. Some bacteria are not easily killed because of  
(a) Chitinous wall (b) Endospore formation  
(c) Presence of mesosome (d) High tolerance
7. Identify the correct pair of events when temperate phages infect bacteria

I. No prophages are formed  
II. Bacterial cell undergoes many divisions  
III. Bacterial cell undergoes immediate lysis  
IV. Prophages are formed

The correct pair is [EAMCET 2009]

(a) I, II (b) II, III  
(c) III, IV (d) II, IV

8. Why the food can be kept for a longer time in cold house than in normal conditions

(a) Insect can not enter  
(b) Bacterial multiplication stops  
(c) Bacterial multiplication is reduced  
(d) There is plasmolysis at low temperature

9. Viral genome incorporated and integrates with bacterial genomes is refer to as [AFMC 2005]  
(a) Prophages (b) RNA  
(c) DNA (d) Both (b) and (c)
10. Sexual reproduction in eubacteria takes place by [AFMC 2012]  
(a) Conjugation (b) Transduction  
(c) Transformation (d) All of these
11. In Griffith's experiment, the conversion of R-type to S-type of *Diplococcus Pneumoniae* when mixed with heat killed S-type is called [MPPMT 1997, 98, 2000, 09; Kerala PMT 2000, 09; CBSE PMT 2002; DUMET 2010; MHCET 2015]

Or

The uptake of naked DNA by bacteria is called

[WB JEE 2016]

- (a) Mutation (b) Transduction  
(c) Transfection (d) Transformation
12. There is no alternation of generation in *Escherichia coli* because there is no [CBSE PMT 1994]  
(a) Syngamy (b) Reduction division  
(c) Conjugation (d) None of these
13. Penicillin inhibits bacterial multiplication because [CPMT 1998; Odisha JEE 2008]  
(a) It checks spindle formation  
(b) It destroys chromatin  
(c) It inhibits cell wall formation  
(d) It checks RNA synthesis
14. Pili in bacteria represent [BHU 2001]  
(a) Extra-chromosomal genetic element  
(b) Protoplasmic outgrowths of donor cells  
(c) Small flagella  
(d) Special bacterial cilia
15. The process of replication in plasmid DNA, other than initiation, is controlled by [RPMT 1999]  
(a) Plasmid gene (b) Bacterial gene  
(c) Cytoplasmic gene (d) Mitochondrial gene
16. The guts of cow and buffalo possess [AIPMT (Cancelled) 2015]  
(a) *Chlorella* spp. (b) Methanogens  
(c) Cyanobacteria (d) *Fucus* spp.
17. Transfer of genetic information from one bacterium to another in the transduction process is through [CBSE PMT 1998]  
(a) Physical contact between donor and recipient strains  
(b) Conjugation between opposite strain bacterium  
(c) Bacteriophages released from the donor bacterial strain  
(d) Another bacterium having special organ for conjugation
18. Conjugation in bacteria was discovered by [MP PMT 2000]

Or

The sexuality in bacteria was established by [MP PMT 1996]

- (a) Robert Koch (b) Schaudinn and Hoffmann  
(c) Lederberg and Tatum (d) Leeuwenhoek

19. Transfer of DNA from one bacteria to another by contact is known as [Kerala CET 2001]  
(a) Conjugation (b) Transformation  
(c) Transduction (d) Transcription
20. Sex factor in bacteria is [CBSE PMT 1996; BHU 1999]  
(a) F-replicon (b) Chromosomal replicon  
(c) RNA (d) Sex pili
21. Amitosis is shown by [CPMT 2010]  
(a) Bacteria (b) *Euglena*  
(c) *Syllis* (d) *Hydra*
22. Bacteria reproduce sexually by [MP PMT 2000]  
(a) Endospores (b) Transformation  
(c) Conidia (d) Exospores

### Economic importance of bacteria

1. Consider the following four statements (1-4) and select the option which includes all the correct ones only  
(1) Single cell *Spirulina* can produce large quantities of food-rich in protein, minerals, vitamins etc  
(2) Body weight-wise the microorganism *Methylophilus methylotrophus* may be able to produce several times more proteins than the cows per day  
(3) Common button mushrooms are a very rich source of vitamin C  
(4) A rice variety has been developed which is very rich in calcium
- Options** [CBSE PMT (Mains) 2012]  
(a) Statements (3), (4)  
(b) Statements (1), (3) and (4)  
(c) Statements (2), (3) and (4)  
(d) Statements (1), (2)
2. A free living anaerobic bacterium capable of  $N_2$  fixation in soil is [RPMT 1995; MP PMT 1996, 2006; BHU 1998, 2012; HPMT 2000]  
(a) *Rhizobium* (b) *Azotobacter*  
(c) *Streptococcus* (d) *Clostridium*
3. Which of the following is free-living aerobic non-photosynthetic nitrogen fixing bacterium [CBSE PMT 1997; BHU 2002, 03, 08; J & K CET 2005, 08; DUMET 2009; Odisha JEE 2010; MP PMT 2012]  
(a) *Rhizobium* (b) *Azotobacter*  
(c) *Nostoc* (d) *Azospirillum*
4. Which of the following groups of plants are highly useful in increasing soil fertility  
(a) Red algae (b) Fungi  
(c) Bacteria (d) Bryophytes
5. A prokaryotic autotrophic nitrogen fixing symbiont found in [NCERT; CBSE PMT (Pre.) 2011]  
**Or**  
Besides paddy fields, cyanobacteria are also found inside vegetative part of [NEET 2013]  
(a) *Pisum* (b) *Alnus*  
(c) *Cycas* (d) *Cicer*
6. Curing of tea leaves is brought about by the activity of [CBSE PMT 2006]  
(a) Viruses (b) Fungi  
(c) Bacteria (d) Mycorrhiza

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7. Oxygenic photosynthesis occurs in [CBSE PMT 2009]  
 (a) Chromatium (b) Oscillatoria  
 (c) Rhodospirillum (d) Chlorobium
8. *Thermococcus*, *Methanococcus* and *Methanobacterium* exemplify [CBSE PMT 2008]  
 (a) Bacteria whose DNA is relaxed or positively supercoiled but which have a cytoskeleton as well as mitochondria  
 (b) Bacteria that contain a cytoskeleton and ribosomes  
 (c) Archaeobacteria that contain protein homologous to eukaryotic core histones  
 (d) Archaeobacteria that lack any histones resembling those found in eukaryotes but whose DNA is negatively supercoiled
9. The symbiotic nitrogen fixing bacteria present in root nodules of legumes belong to genus [NCERT; AFMC 1998; CPMT 1998; CBSE PMT 1999; Pb. PMT 1999; BVP 2002; Kerala CET 2003; MP PMT 2003; MHCET 2004; AIEEE Pharmacy 2004; Bihar CECE 2006; DUMET 2009; J & K CET 2010]  
 (a) *Xanthomonas* (b) *Pseudomonas*  
 (c) *Rhizobium* (d) *Acetobacter*
10. Nitrogen fixing bacteria are associated with [NCERT]  
 (a) Leguminosae (b) Cruciferae  
 (c) Gramineae (d) Malvaceae
11. Which of the following is recently discovered gram positive non-leguminous nitrogen fixing bacterium [AIEEE Pharmacy 2003]  
 (a) *Azospirillum* (b) *Rhizobium*  
 (c) *Nitrosomonas* (d) *Spirillum*
12. Nitrifying bacteria, *Nitrosomonas* and *Nitrobacter* [CPMT 2004; Odisha JEE 2010; CBSE PMT (Pre.) 2011]  
 (a) Convert (oxidise) ammonia or ammonium compounds into nitrates  
 (b) Convert nitrate into nitrogen  
 (c) Convert nitrogen into nitrates  
 (d) Convert carbon dioxide into carbohydrates
13. Match the items in column I with those in column II and choose the correct answer
- |    | Column I                             |      | Column II              |
|----|--------------------------------------|------|------------------------|
| P. | Blue green algae as biofertilizers   | i.   | <i>Ectomycorrhiza</i>  |
| Q. | Fungi as biofertilizers              | ii.  | <i>Thiobacillus sp</i> |
| R. | Free living nitrogen fixing bacteria | iii. | <i>Anabaena sp</i>     |
| S. | Phosphate solubilizing bacteria      | iv.  | <i>Clostridium sp</i>  |
|    |                                      | v.   | <i>Azospirillum sp</i> |
- [WB JEE 2012]
- (a) P-iii, Q-i, R-v, S-ii (b) P-v, Q-i, R-ii, S-iv  
 (c) P-v, Q-iv, R-i, S-ii (d) P-iv, Q-ii, R-v, S-iii
14. The most abundant prokaryotes helpful to humans in making curd from milk and in production of antibiotics are the ones categorised as [CBSE PMT (Pre.) 2012]  
 (a) Cyanobacteria  
 (b) Archaeobacteria  
 (c) Chemosynthetic autotrophs  
 (d) Heterotrophic bacteria
15. During biological nitrogen fixation, inactivation of nitrogenase by oxygen poisoning is prevented by [AIPMT 2015]  
 (a) Xanthophyll (b) Carotene  
 (c) Cytochrome (d) Leghaemoglobin
16. Free living bacteria that can fix  $N_2$  from soil is [Odisha JEE 2012]  
 (a) *Clostridium* (b) *Azotobacter*  
 (c) *Beijerinckia* (d) All of these
17. For retting of jute the fermenting microbe used is [CBSE PMT 2005]  
 (a) *Methophilic bacteria* (b) Butyric acid  
 (c) *Helicobacter pylori* (d) *Streptococcus lactis*
18. Which bacteria is responsible for the reduction of nitrates into nitrogen, (denitrifying Bacteria) in soil [Odisha JEE 2005; Kerala PMT 2010; AMU (Med.) 2010; MP PMT 2010; J & K CET 2012]  
 (a) *Nitrosomonas* (b) *Pseudomonas*  
 (c) *Rhizobium* (d) *Clostridium*
19. Which of the bacterium is useful in preparing Idli [BVP 2003]  
 (a) *Leuconostoc mesenteroides*  
 (b) *Clostridium*  
 (c) Both (a) and (b)  
 (d) None of the above
20. Which of the following is symbiotic nitrogen fixes [DPMT 2006; CBSE PMT 2009]  
 Or  
 Which of the following can fix nitrogen in non-leguminous plants [WB JEE 2016]  
 (a) *Streptomyces* (b) *Anabaena*  
 (c) *Frankia* (d) *Rhizobium*
21. Non-symbiotic nitrogen fixation takes place by [GUJCET 2014]  
 (a) *Nostoc*, *Azotobacter*, *Clostridium*  
 (b) *Anabena*, *Nostoc*, *Rhizobium*  
 (c) *Azotobacter*, *Nitrosomonas*, *Rhizobium*  
 (d) *Anabena*, *Nitrosomonas*, *Pseudomonas*
22. All of the following statements concerning the actinomycetous filamentous soil bacterium *Frankia* are correct except that *Frankia* [CBSE PMT 2005]  
 (a) Can induce root nodules on many plant species  
 (b) Cannot fix nitrogen in the free-living state  
 (c) Cannot fix specialized vesicles in which the nitrogenase is protected from oxygen by a chemical barrier involving terpenoid hapanoids  
 (d) Like *Rhizobium*, it usually infects its host plant through root hair deformation and stimulates cell proliferation in the host's cortex



23. Organisms called Methanogens are most abundant in a  
[CBSE PMT (Pre.) 2011]  
(a) Hot spring (b) Sulphur rock  
(c) Cattle yard (d) Polluted stream
24. Plasmid are used as carrier because  
[CBSE PMT 2000; AIIMS 2007]  
(a) It has antibiotic resistance genes  
(b) Its both ends are replication points  
(c) It can go between eukaryotic and prokaryotic cells  
(d) It is circular DNA which has capacity to bind eukaryote DNA
25. Fermentation is by  
[RPMT 1999]  
(a) All micro organism  
(b) All fungi  
(c) All bacteria  
(d) Some fungi and some bacteria
26. Cattle ranches are known to cause acute green house effect. This is due to  
[AIIMS 2012]  
(a) Mechanised milking practices  
(b) Methanogenic bacteria in rumen  
(c) Decomposition of left over fodder  
(d) Decomposition of organic remains in faeces
27. Which does not help in  $N_2$  fixation  
[RPMT 1999]  
(a) *Anabaena* (b) *Nostoc*  
(c) *Oscillatoria* (d) *Rhizobium*
28. Which of the following is non-symbiotic biofertilizer  
[CBSE PMT 1998]  
(a) VAM (b) *Azotobacter*  
(c) *Anabaena* (d) *Rhizobium*
29. Which bacteria convert ammonium salts into nitrite  
[CPMT 1998]  
(a) *Nitrobacter* (b) *Nitrosomonas*  
(c) *Azotobacter* (d) None of these
30. Which of the following soil microorganism breaks down plant and animal protein into ammonia  
[KCET 1998]  
(a) *Bacillus vulgaris* (b) *Nitrosomonas*  
(c) *Pseudomonas* (d) None of the above
31. Which of the following is used to cure off the bitterness of tea leaves  
[CPMT 1999; JIPMER 2001]  
(a) *Bacillus subtilis* (b) *B. megatherium*  
(c) *B. lactis* (d) *B. mycoccoccus*
32. One of the useful activities of several bacteria is  
[MP PMT 1998]  
(a) Nitrogen fixation  
(b) Nitrification  
(c) Operation of biogeochemical cycles  
(d) All of the above
33. The main role of bacteria in the carbon cycle involves  
[CBSE PMT 1998; AIIMS 2000]  
(a) Photosynthesis  
(b) Assimilation of nitrogenous compounds  
(c) Chemosynthesis  
(d) Digestion or breakdown of organic compounds
34. One of the free-living, anaerobic nitrogen-fixer is  
[CBSE PMT (Pre.) 2010]  
Or  
Which of the following is a photoautotrophic bacterium  
[CBSE PMT 2014]  
(a) *Azotobacter* (b) *Beijernickia*  
(c) *Rhodospirillum* (d) *Rhizobium*
35. The function of leghaemoglobin in the root nodules of legumes is  
[NCERT; CBSE PMT (Pre.) 2011]  
(a) Expression of *nif* gene  
(b) Inhibition of nitrogenase activity  
(c) Oxygen removal  
(d) Nodule differentiation
36. A large number of organic compounds can be decomposed by  
[CBSE PMT 1995]  
(a) Chemoorgano (b) *Pseudomonas*  
(c) *Acetobacter* (d) *Mycoplasma*
37. Which one of the following bacteria has potential for nitrogen fixation  
[MP PMT 1995; Bihar MDAT 1995]  
(a) *Nitrosomonas* (b) *Nitrobacter*  
(c) *Nitrosococcus* (d) *Rhizobium*
38. Certain bacteria living in the soil poor in oxygen convert nitrates into nitrites and then to free nitrogen and such bacteria are termed as  
[KCET 2000; CPMT 2003; AFMC 2006]  
Or  
The bacteria which convert  $NO_3 \rightarrow \text{Free } N_2$  are called as  
[CPMT 1994, 2003; MP PMT 1996; MHCET 2003]  
(a) Nitrogen fixing bacteria (b) Denitrifying bacteria  
(c) Ammonifying bacteria (d) Saprophytic bacteria
39. Which of the following is a flowering plant with nodules containing filamentous nitrogen-fixing microorganism  
[CBSE PMT 2007]  
(a) *Casuarina equisetifolia* (b) *Crotalaria juncea*  
(c) *Cycas revoluta* (d) *Cicer arietinum*
40. Probiotics are  
[CBSE PMT 2007; DUMET 2010]  
(a) Safe antibiotics  
(b) Cancer inducing microbes  
(c) New kind of food allergens  
(d) Live microbial food supplement
41. Bacteria which directly convert atmospheric nitrogen into nitrogen compounds are called  
[AFMC 1996]  
(a) Denitrifying bacteria (b) Putrefying bacteria  
(c) Nitrogen fixing bacteria (d) Nitrifying bacteria

### Bacterial diseases

1. The germ theory of disease was put forth by [MP PMT 1995]  
(a) Koch (b) Pasteur  
(c) Rayer (d) Devaine
2. Effective management practice for bacterial leaf blight of rice is  
[Odisha JEE 2012]  
(a) Removal of secondary host weed  
(b) Use of resistant varieties  
(c) Treatment of  $ZnSO_4$  and  $CaOCl_2$   
(d) All of the above
3. In the following table identify the correct matching of the crop, its disease and the corresponding pathogen [AIIMS 2008]
- | Crop           | Disease     | Pathogen                         |
|----------------|-------------|----------------------------------|
| (a) Citrus     | Canker      | <i>Pseudomonas rubritlineans</i> |
| (b) Potato     | Late blight | <i>Fusarium udum</i>             |
| (c) Brinjal    | Root-knot   | <i>Meloidogyne incognita</i>     |
| (d) Pigeon pea | Seed gall   | <i>Phytophthora infestans</i>    |
4. Cause of 'Mad Cow' disease of England [RPMT 1999]  
(a) Virions (b) *Mycoplasma*  
(c) Scrapie Protein (d) Viral protein

5. Which of the following is a bacterial plant disease  
[Odisha JEE 2010]
- Tikka disease of groundnut
  - Downy mildew of grapes
  - Ring rot of potato
  - Red rot of sugarcane
6. Mycolic acid is present in cell wall of pathogen causing
- Tetanus
  - Cholera
  - Diphtheria
  - Tuberculosis
7. Tetanolysin is produced by
- Mycobacterium laprae*
  - Clostridium botulinum*
  - Clostridium tetani*
  - None of these
8. Bacterial blight of rice is caused due to  
[Odisha JEE 2004; CBSE PMT 2008]
- Xanthomonas oryzae*
  - Helminthosporium oryzae*
  - Pseudomonas falcatum*
  - Xanthomonas falcatum*
9. The poisonous substances commonly produced by bacteria are known as  
[Kerala CET 2002; AFMC 2003]
- Toxin (Exotoxins)
  - Auxins
  - Antibiotic
  - Antitoxins
10. Which one of the following pathogen cause canker disease  
[MP PMT 2002, 10; Kerala PMT 2007]
- Meloidogyne Incognita*
  - Anguina tritici*
  - Xanthomonas citri*
  - Pseudomonas rubillneans*
  - Phytophthora infestans*
11. The *Bacillus haemophilus* causes
- Influenza
  - Pneumonia
  - A form meningitis
  - Whooping cough
12. Black rot of crucifers is caused by a  
[AMU (Med.) 2012]
- Fungus
  - Bacterium
  - Virus
  - None of these
13. Which of the following is disease causing bacterium in human beings  
[MP PMT 2002]
- Escherichia coli*
  - Xanthomonas citri*
  - T.M.V.
  - Pilobolus
14. "Crown gall" is caused by  
[BHU 1995; CPMT 1998]
- Mycobacterium*
  - Agrobacterium tumefaciens*
  - Erwinia*
  - Clostridium*
15. Which is the cause of Anthrax disease  
[MP PMT 2002]
- Virus
  - Bacteria
  - Mycoplasma
  - Algae
16. 'Citrus canker' is caused by a  
[NCERT; MP PMT 1997; BVP 2000; AFMC 2008]
- Fungus
  - Bacterium
  - Virus
  - Nematoda
17. The 2005 noble prize for physiology/medicine was awarded to Barry Marshall and Robin Warren of Australia for their discovery of  
[KCET 2011]
- Human papilloma virus causing cervical cancer
  - Bacterium *Helicobacter pylori* causing peptic ulcer
  - Prions, a new biological principle of infection
  - Human immunodeficiency virus

## Mycoplasma

1. Which one is the smallest organism capable of autonomous growth and reproduction  
[MP PMT 2001; BHU 2012]
- Or
- Which among the following are the smallest living cells, known without a definite cell wall, pathogenic to plants as well as animals and can survive without oxygen [NEET 2017]
- Virus
  - Viroid
  - Mycoplasma (PPLO)
  - None of the above
2. Little leaf of brinjal is caused by  
[Bihar MDAT 1995; MP PMT 2001]
- Virus
  - Mycoplasma
  - Fungus
  - Algae
3. Which one of the following statements about mycoplasma is wrong  
[MP PMT 2002; CBSE PMT 2007]
- They are also called PPLO
  - They are pleomorphic
  - They are sensitive to penicillin
  - They cause diseases in plants
4. What is incorrect for mycoplasma  
[RPMT 1997]
- They are osmotically inactive
  - Show absence of cell wall
  - Are sensitive to modern antibiotics
  - Are obligate intracellular parasites
5. Prokaryota includes  
[RPMT 1995; CBSE PMT 1996; JIMPER 2002; MP PMT 2004]
- Mycoplasma
  - Ulothrix
  - Fungi
  - Mycoplasma and blue-green algae
6. Penicillin and Vancomycin do not affect the mycoplasma because  
[Odisha JEE 2008]
- There is no cell wall
  - There is no nucleus
  - There is no mitochondria
  - There is no golgi body
7. Which of the following is effective against mycoplasmal diseases
- Vancomycin
  - Penicillin
  - Chloramphenicol
  - All the above
8. Which of the following is called "Jockers of microbiological park"
- Bacteria
  - Mycoplasma
  - Nostoc
  - None of these
9. The 'Witches broom' of legumes is caused by a  
[MP PMT 1994; RPMT 1995; KCET 1999; Pb. PMT 2004]
- Virus
  - Mycoplasma
  - Bacterium
  - Fungus
10. Elementary cell body in mycoplasma perform the function of  
[RPMT 1995; MP PMT 1995, 98]
- Metabolism
  - Excretion
  - Reproduction
  - Respiration
11. Mycoplasma are not sensitive to  
[MP PMT 2000]
- Streptomycin
  - Penicillin
  - Erythromycin
  - Neomycin
12. Which of the following statement is true for Mycoplasma  
[MP PMT 1999; KCET 2015; AIPMT 2015]
- Presence of cell wall
  - Presence of nucleus
  - Absence of cell wall
  - Definite shape

13. Who recorded pleuropneumonia in cattles  
(a) Pasteur (b) Twort  
(c) Knoll and Ruska (d) Nocard and Roux
  14. "Dodder" can transmit  
(a) Mycoplasmal diseases (b) Viral diseases  
(c) Both (a) and (b) (d) None of these
  15. Which of the species of mycoplasma causes human sterility  
(a) *M. hominis* (b) *M. fermentans*  
(c) Both (a) and (b) (d) None of these
  16. The outermost limiting layer of mycoplasma is made up of  
(a) Cell wall (b) Cell membrane  
(c) Mucilaginous sheath (d) Silime layer  
[Odisha JEE 2002]
  17. The membrane of which one of the following micro-organism is three layered  
(a) *Nostoc* (b) *Mycoplasma*  
(c) *E. coli* (d) *Rhodospirillum*
  18. The disease of cardio-vascular system is caused by  
(a) Algae (b) Mycoplasma  
(c) Cyanobacteria (d) None of these
  19. Tendency of abortion in ladies is caused by [MP PMT 2007]  
(a) Cyanobacteria (b) Bacteria  
(c) Mycoplasma (d) None of these
  20. Which disease is caused by mycoplasma  
(a) Citrus greening (b) Sandal spike  
(c) Grassy shoot of sugarcane (d) All the above
  21. Mycoplasma is  
(a) Gram positive  
(b) Gram negative  
(c) Some species are gram positive  
(d) None of the above
  22. PPLO reproduce (multiply) by  
(a) Gametic fusion (b) Binary fission  
(c) Akinetes (d) Endospore
  23. An organism having cytoplasm DNA and RNA but no cell wall is  
(a) Cyanobacterium (b) Mycoplasma  
(c) Bacterium (d) Virus  
[MP PMT 1995, 98; CPMT 2000; BVP 2001; MHCET 2002]
  24. Mycoplasma is related to  
(a) Algae (b) Bacteriophage  
(c) Virus (d) L-form bacteria
  25. Organisms without any specific shape are [MP PMT 1997]  
(a) Mycoplasmas (b) Bacteria  
(c) Viruses (d) Cyanobacteria
- Cyanobacteria / Blue green algae**
1. Pigment phycocyanin and phycoerythrin are found in  
(a) Bacillariophyceae (b) Archaeobacteria  
(c) Eubacteria (d) Cyanobacteria  
(e) Chlorophyceae  
[Kerala CET 2005, BHU 2008]
  2. Incipient nucleus is present in [BVP 2000]  
(a) Chlorophyceae (b) Rhodophyceae  
(c) Myxophyceae (d) Phaeophyceae
  3. Which of the following has polar nodule on both the ends  
(a) Akinetes (b) Hormogonia  
(c) Heterocysts (d) None of these
  4. Which of the following shows the absence of chlorophyll 'b'  
(a) Green algae (b) Red algae  
(c) Blue-green algae (d) Brown algae  
[DPMT 2006]
  5. Which of the following plants is used as biofertiliser  
(a) *Nostoc* (b) *Funaria*  
(c) *Volvox* (d) *Rhizopus*  
[Kerala CET 2005]
  6. The most primitive in the following are [BHU 2005]  
(a) Cyanobacteria (b) Bryophytes  
(c) Gymnosperms (d) Monocots
  7. Which of the following statements is right [KCET 2004]  
(a) Fronds are found in bryophytes  
(b) Multiciliate sperms are found in angiosperms  
(c) Diatoms produce basidiospores  
(d) Heterocysts are found in *Nostoc*
  8. Cyanobacteria are [DPMT 2002; BVP 2004]  
(a) Mosses which attack bacteria  
(b) Bacteria which attack cyanophyceae  
(c) Autotrophic organism with phycocyanin  
(d) None of these
  9. Nitrogen fixation by *Nostoc*/*Anabaena* takes place in  
(a) Heterocysts (b) Vegetative cells  
(c) Akinetes (d) Hormogonia  
[NCERT; MP PMT 1996; Odisha JEE 2004, 09; AFMC 2009; NEET (Karnataka) 2013]
  10. Which of the following may cause water blooms  
(a) Bacteria (b) Mycoplasma  
(c) Virus (d) Blue-green algae  
[NCERT; BVP 2004]
  11. Which of the following is not a blue-green algae  
(a) *Nostoc* (b) *Anabaena*  
(c) Lichen (d) *Aulosiras*  
[CPMT 2004]
  12. The blue-green algae are so called as they have in addition to green pigment chlorophyll, a blue pigment known as  
(a) Phycocyanin (b) Chromoplasm  
(c) Cyanophycin (d) Phycoerythrin  
[KCET 1994; MP PMT 1996; Kerala PMT 2003]
  13. Red sea phenomena due to [RPMT 2006]  
(a) Red algae  
(b) Dinophyceae  
(c) Diatoms  
(d) Blue-green algae (*Trichodesmium erythrum*)
  14. Which of the following movement may be found in blue-green algae  
(a) Flagellar (b) Ciliary  
(c) Gliding (d) None of the above

15. Which of the following important features are found in blue-green algae [MP PMT 2006]  
 (a) Abundant secretion of pectin  
 (b) Presence of phycocyanin – C as dominant pigment  
 (c) No plastids  
 (d) All the above
16. Which was first photosynthetic organism [DPMT 2003]  
 (a) Green algae (b) Red algae  
 (c) Cyanobacteria (d) Brown algae
17. Which of the following is a Prokaryote [MP PMT 2002]  
 (a) *Chlorella* (b) *Chlamydomonas*  
 (c) *Protomyces* (d) *Oscillatoria*
18. What is the photosynthetic product in blue-green algae  
 (a) Normal starch  
 (b) Glycogen  
 (c) Cyanophycean starch resembling glycogen  
 (d) None of these
19. Which is not a cyanobacterium [AFMC 2002]  
 (a) *Lyngbya* (b) *Plectonema*  
 (c) *Anabaena* (d) *Sinorhizobium*
20. The characteristic of blue green algae is [NCERT; CBSE PMT 1999; RPMT 1999, 2002]  
 Or  
 Blue-green algae are called cyanobacteria because [MP PMT 2012]  
 (a) DNA without histone  
 (b) Nuclear membrane absent  
 (c) 70 S ribosomes  
 (d) All of the above
21. Cyanobacteria of great nutritive value is [Kerala CET 2001]  
 (a) *Gleocapsa* (b) *Scytonema*  
 (c) *Stigonema* (d) *Spirulina*
22. Nitrogenase enzyme is found in *Nostoc* in the cell of [MP PMT 2001]  
 (a) Vegetative (b) Heterocyst  
 (c) Both (a) and (b) (d) None of these
23. *Nostoc* is known to perform [MP PMT 2001]  
 (a) Only photosynthesis  
 (b) Photosynthesis and nitrogen fixation simultaneously  
 (c) Only nitrogen fixation  
 (d) Either photosynthesis or nitrogen fixation at a time
24. Single filament of *Nostoc* without mucilage sheath is known as [AIIMS 1998]  
 (a) Hyphae (b) Colony  
 (c) Trichome (d) Mycelium
25. In which of the following there is no sexual reproduction [CBSE PMT 1995, 99; BVP 2001]  
 (a) *Ulothrix* (b) *Nostoc*  
 (c) *Aspergillus* (d) *Volvox*
26. Which of the following algae is symbiotic and nitrogen fixing [Pb. PMT 1999]  
 (a) *Spirogyra* (b) *Cladophora*  
 (c) *Anabaena* (d) *Oedogonium*
27. Sexual reproduction is absent in [MP PMT 2000]  
 (a) Cyanobacteria (b) Bacteria  
 (c) Eukaryote (d) All of the above
28. Prokaryotes are characterized by [Bihar MDAT 1995; CPMT 2009]  
 (a) A true nucleus with double layered nuclear membrane is absent  
 (b) Well developed nucleus with double layered nuclear membrane present  
 (c) Presence of cell wall made of chitins, mucopolysaccharides and absence of nuclear membrane and cell organelles like mitochondria and chloroplasts  
 (d) Autotrophic in nature and only DNA is present
29. One of the followings is not the characteristic feature of cyanobacteria [AMU (Med.) 2010]  
 (a) They are multicellular  
 (b) They form colonies  
 (c) They form blooms in polluted water bodies  
 (d) They can fix atmospheric nitrogen
30. The name cyanobacteria refers to [NCERT; CPMT 2002; CBSE PMT (Pre.) 2012]  
 (a) Bacteria (b) Blue-green algae  
 (c) Yeast (d) Fungi
31. Nuclear membrane is absent in [CBSE PMT (Pre.) 2012]  
 (a) *Penicillium* (b) *Agaricus*  
 (c) *Volvox* (d) *Nostoc*
33. Which one of the following statements is wrong [NEET (Phase-I) 2016]  
 (a) Cyanobacteria are also called blue-green algae  
 (b) Golden algae are also called desmids  
 (c) Eubacteria are also called false bacteria  
 (d) Phycomycetes are also called algal fungi
34. Which were the organisms who changed earth's surface from reducing to the oxidizing [BHU 2001]  
 (a) Autotrophs (b) Heterotrophs  
 (c) Photoautotrophs (d) Chemotrophs
35. Cyanobacteria originated about how many years ago [Pb. PMT 2000]  
 (a) 1 billion (b) 2 billion  
 (c) 3 billion (d) 4 billion
36. Which of the following statements is not true for *Nostoc* [KCET 2012]  
 (a) It is prokaryotic (b) It is autotrophic  
 (c) It is filamentous (d) It is macroscopic
37. During rainy seasons, the ground becomes slippery due to dense growth of [BHU 1999]  
 (a) Lichens (b) Bacteria  
 (c) Green algae (d) Cyanobacteria
38. Hormogonia are the vegetatively reproducing structures of [AIIMS 1999]  
 (a) *Ulothrix* (b) *Spirogyra*  
 (c) *Oscillatoria* (d) *Chlamydomonas*
39. Atmospheric nitrogen-fixation is carried on by [Pb. PMT 1999; HP PMT 2005]  
 (a) *Funaria* (b) *Anabaena*  
 (c) *Chlamydomonas* (d) Fern gametophyte

40. *Spirulina* is a [CPMT 2010]  
(a) Blue green algae (b) Fungi  
(c) Pteridophyte (d) Bryophyte
41. Cyanophyceae has got  
(a) Definite nucleus and plastid  
(b) No definite nucleus but plastid  
(c) Neither definite nucleus nor plastid  
(d) Definite nucleus but no plastid
42. *Nostoc* is a [MP PMT 1999; MHCET 2007]  
(a) Cyanobacteria (b) Beaded bacterium  
(c) Bacteriophage (d) Parasite
43. Unicellular cyanobacteria reproduce asexually by [MP PMT 1997]  
(a) Conjugation (b) Fragmentation  
(c) Binary fission (d) Hormogones
44. Heterocysts are found in certain [MP PMT 1997; Kerala PMT 2010]  
(a) Viruses (b) Bacteria  
(c) Cyanobacteria (d) Mycoplasmas
45. Pigment-containing membranous extensions in some cyanobacteria are [NEET 2013]  
(a) Chromatophores (b) Heterocysts  
(c) Basal bodies (d) Pneumatophores
46. *Nostoc* is characteristic in having [MP PMT 1998]  
(a) Cellulose cell wall (b) Uniflagellated zoospores  
(c) Chlorophyll 'e' (d) Sexual reproduction
4.  $K_{12}$  plasmid was studied first in  
(a) *E. coli* (b) *Shigella*  
(c) *Salmonella* (d) *Eberthella*
5. Lysozyme that is present in perspiration, saliva and tears, destroys [CBSE PMT 2007]  
(a) Certain fungi  
(b) Certain types of bacteria  
(c) All viruses  
(d) Most virus - infected cells
6. The most thoroughly studied of the known bacteria-plant interactions is the [CBSE PMT 2004]  
(a) Nodulation of *Sebania* stems by nitrogen fixing bacteria  
(b) Plant growth stimulation by phosphate-solubilising bacteria  
(c) Cyanobacterial symbiosis with some aquatic ferns  
(d) Gall formation on certain angiosperms by *Agrobacterium*
7. Which one of the following is genetically improved bacteria for pollution control [CPMT 1998]  
(a) *Pseudomonas* (b) *Rhizobium*  
(c) *Nitrobacter* (d) *Nitrosomonas*
8. Otitis media (inflammation of middle ear) is caused by  
(a) Virus (b) Bacteria  
(c) Bacteriophage (d) Mycoplasma
9. Select the correct combination of the statements (A-D) regarding the characteristics of certain organisms  
(A) Methanogens are Archaeobacteria which produce methane in marshy areas  
(B) *Nostoc* is a filamentous blue-green algae which fixes atmospheric nitrogen  
(C) Chemosynthetic autotrophic bacteria synthesize cellulose from glucose  
(D) Mycoplasma lack a cell and can survive without oxygen  
The correct statements are [CBSE PMT (Mains) 2010]  
(a) (B), (C) (b) (A), (B), (C)  
(c) (B), (C), (D) (d) (A), (B), (D)
10. The gram negative bacteria detect and responded to chemicals in their surroundings by [Kerala CET 2000; WB JEE 2008]  
(a) Lipopolysaccharide (b) Muramic acid  
(c) Porins (d) Volutin granules
11. A few organisms are known to grow and multiply at temperatures of 100 – 105°C. They belong to [CBSE PMT 1998]  
(a) Thermophilic subaerial fungi  
(b) Marine archaeobacteria  
(c) Thermophilic sulphur bacteria  
(d) Hot spring blue-green algae
1. *Escherichia coli* has the following combination of characters  
(a) Rod shaped, 1–3  $\mu\text{m}$  long, gram negative  
(b) Rod shaped, 1– 3  $\mu\text{m}$  long, gram positive  
(c) Spiral, 1–3  $\mu\text{m}$  long, gram negative  
(d) Spiral, 1–3  $\mu\text{m}$  long, gram positive
2. Mycoplasma differs from virus in being sensitive to [MP PMT 1995]  
(a) Sugar (b) Tetracycline  
(c) Protein (d) Amino acid
3. Which one of the following is wrong statement [CBSE PMT (Pre.) 2012]  
(a) *Anabaena* and *Nostoc* are capable of fixing nitrogen in free living state also  
(b) Root nodule forming nitrogen fixers live as aerobes under free living conditions  
(c) Phosphorus is a constituent of all membranes, certain nucleic acids and all proteins  
(d) *Nitrosomonas* and *Nitrobacter* are chemoautotrophs



Critical Thinking

Objective Questions

12. A bacterium divides every 35 minutes. If a culture containing  $10^5$  cells / ml is grown for 175 minutes. What will be the cell concentration / ml after 175 minutes

[CBSE PMT 1998; BHU 2004]

- (a)  $175 \times 10^5$  cells (b)  $85 \times 10^5$  cells  
(c)  $35 \times 10^5$  cells (d)  $32 \times 10^5$  cells

13. Monera possess [MP PMT 2013]

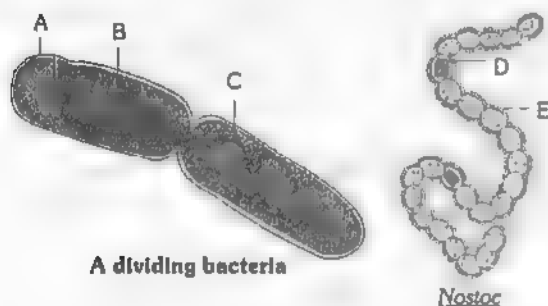
- (a) Membrane bound nucleoproteins lying free in the cytoplasm  
(b) Gene containing nucleoproteins condensed together in compact masses  
(c) Nucleoproteins in direct contact with the rest of the cell substance  
(d) Only free nucleic acid aggregates

14. Which of the following are likely to be present in deep sea water [NEET 2013]

- (a) Saprophytic fungi (b) Archaeobacteria  
(c) Eubacteria (d) Blue-green algae

15. Identify the A, B, C, D and E in the following diagram

[NCERT]



- (a) A – Cell membrane, B – Cell wall, C – DNA, D – Heterocyst, E – Mucilaginous sheath  
(b) A – Mucilaginous sheath, B – Cell membrane, C – DNA, D – Heterocyst, E – Cell wall  
(c) A – Cell wall, B – Cell membrane, C – DNA, D – Heterocyst, E – Mucilaginous sheath  
(d) A – Cell wall, B – Cell membrane, C – Heterocyst, D – DNA, E – Mucilaginous sheath

16. The motile bacteria are able to move by [CBSE PMT 2014]

- (a) Cilia (b) Pili  
(c) Fimbriae (d) Flagella

17. Pick up the wrong statement [AIPMT 2015]

- (a) Protista have photosynthetic and heterotrophic modes of nutrition  
(b) Some fungi are edible  
(c) Nuclear membrane is present in monera  
(d) Cell wall is absent in animalia

18. Cyanobacteria are classified under [NCERT]

- (a) Protista (b) Plantae  
(c) Monera (d) Algae

19. Conversion of nitrate to ammonia is a/an [WB JEE 2016]

- (a) Amination process (b) Deamination process  
(c) Oxidative process (d) Reductive process

20. Select the mismatch [NEET (Phase-II) 2016]

- (a) Methanogens-Prokaryotes  
(b) Gas vacuoles-Green bacteria  
(c) Large central vacuoles-Animal cells  
(d) Protists-Eukaryotes

21. Select the wrong statement [NEET (Phase-II) 2016]

- (a) *Mycoplasma* is a wall-less microorganism  
(b) Bacterial cell wall is made up of peptidoglycan  
(c) Pili and fimbriae are mainly involved in motility of bacteria cells  
(d) Cyanobacteria lack flagellated cells

22. Spliceosomes are not found in cells of [NEET 2017]

- (a) Plants (b) Fungi  
(c) Animals (d) Bacteria

## Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

- (a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion  
(b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion  
(c) If the assertion is true but the reason is false  
(d) If both the assertion and reason are false  
(e) If the assertion is false but reason is true

- Assertion : Bacteria are prokaryotic.  
Reason : Bacteria do not possess true nucleus and membrane bound cell organelles. [AIIMS 1996]
- Assertion : Bacteria have three basic shapes, i.e., round, rod, spiral.  
Reason : Cocci and Bacilli may form clusters or chain of a definite length. [AIIMS 2000]
- Assertion : Bacterial photosynthesis occurs by utilizing wavelength longer than 700 nm.  
Reason : Here reaction centre is B-890. [AIIMS 2002]
- Assertion : The nitrogen-fixing bacteria in leguminous plant nodules live as symbionts.  
Reason : Leg-haemoglobin synthesized by leguminous plants protect bacteria.
- Assertion : Bacteria are classified among plants.  
Reason : They have cell walls.
- Assertion : Bacteria do not always move with the help of flagella.  
Reason : Flagellated bacteria employs rotary motion of flagellum when it moves.
- Assertion : Some bacteria have the capacity to retain Gram stain after treatment with acid alcohol.  
Reason : They are known as Gram positive as they are attracted towards positive pole under influence of electric current.



8. Assertion : None autotrophic bacteria carry out chemosynthesis.  
Reason : Chemosynthetic bacteria trap the small amount of energy released from inorganic compound's oxidation to use in the reactions that synthesize carbohydrates.
9. Assertion : Exotoxins are released by Gram +ve bacteria causing diseases to animals.  
Reason : Exotoxins are proteins to whose response WBC of animals react.
10. Assertion : All food chains will come to stand still if bacteria disappear from earth.  
Reason : Bacteria are only associated with the soil fertility and hardly any role for food chains.
11. Assertion : Broad spectrum antibiotics are produced by *streptomyces*.  
Reason : They can destroy microorganisms by inhibiting DNA replication or protein synthesis.
12. Assertion : Bacterial cell wall is characterised by having mucopolysaccharides.  
Reason : Acetyl muramic acid is an example of mucopolysaccharide.
13. Assertion : Root nodules in leguminous plants are inhabited by *Anabaena*.  
Reason : Leguminous plants are an example of symbiotic nitrogen fixation.
14. Assertion : *Bacillus butschli* is true bacterium.  
Reason : Its cell wall is composed of acetyl muramic acid.
15. Assertion : Plasmids are double-stranded extra chromosomal DNA.  
Reason : Plasmids are possessed by eukaryotic cells. [AIIMS 1997]
16. Assertion : Pili are motile appendages of bacteria.  
Reason : Pili participate in conjugation.
17. Assertion : Cell secretion does not occur in bacteria.  
Reason : Golgi complex is absent in bacteria.
18. Assertion : *Agrobacterium tumefaciens* is the causative agent of crown gall disease of dicots.  
Reason : *Agrobacterium tumefaciens* causes infection by entering the plant through wounds and injuries. [KCET 2012]

21	d	22	c	23	c	24	c	25	a
26	d	27	a	28	a	29	c	30	c
31	a	32	d	33	a	34	a	35	b
36	b	37	a	38	b	39	d	40	a
41	c	42	a	43	b	44	b	45	b
46	c	47	c	48	d	49	a	50	d
51	c	52	d	53	a	54	c	55	a
56	b	57	c	58	c	59	d	60	c
61	b	62	b	63	a	64	c	65	c
66	b	67	c	68	d	69	b	70	b
71	c	72	d	73	c	74	d	75	c
76	b	77	a	78	c	79	a	80	d

### Life cycle/Reproduction in bacteria

1	a	2	b	3	a	4	a	5	a
6	b	7	d	8	c	9	a	10	d
11	d	12	b	13	c	14	b	15	b
16	b	17	c	18	c	19	a	20	a
21	a	22	b						

### Economic importance of bacteria

1	d	2	d	3	b	4	c	5	c
6	c	7	b	8	c	9	c	10	a
11	a	12	a	13	a	14	d	15	d
16	d	17	b	18	b	19	a	20	c
21	a	22	b	23	c	24	a	25	d
26	b	27	c	28	b	29	b	30	a
31	b	32	d	33	d	34	c	35	c
36	a	37	d	38	b	39	a	40	d
41	c								

### Bacterial diseases

1	b	2	d	3	c	4	c	5	c
6	d	7	c	8	a	9	a	10	c
11	a	12	b	13	a	14	b	15	b
16	b	17	b						

### Structure, shape and nutrition of bacteria

1	c	2	d	3	b	4	c	5	d
6	a	7	c	8	c	9	a	10	b
11	c	12	a	13	b	14	a	15	b
16	e	17	a	18	b	19	a	20	b

## Answers

## Mycoplasma

1	c	2	b	3	c	4	d	5	d
6	a	7	c	8	b	9	b	10	c
11	b	12	c	13	d	14	c	15	c
16	b	17	b	18	b	19	c	20	d
21	b	22	b	23	b	24	d	25	a

## Cyanobacteria / Blue green algae

1	d	2	c	3	c	4	c	5	a
6	a	7	d	8	c	9	a	10	d
11	c	12	a	13	d	14	c	15	d
16	c	17	d	18	c	19	d	20	d
21	d	22	b	23	b	24	c	25	b
26	c	27	a	28	c	29	a	30	b
31	d	32	c	33	c	34	c	35	d
36	d	37	c	38	b	39	a	40	c
41	a	42	c	43	c	44	a	45	a

## Critical Thinking Questions

1	a	2	b	3	c	4	a	5	b
6	d	7	a	8	d	9	d	10	c
11	d	12	d	13	c	14	b	15	c
16	d	17	c	18	c	19	d	20	c
21	c	22	d						

## Assertion and Reason

1	a	2	b	3	b	4	a	5	a
6	b	7	c	8	d	9	a	10	c
11	a	12	d	13	a	14	a	15	c
16	e	17	e	18	a				

# AS

## Answers and Solutions

## Structure, shape and nutrition of bacteria

5. (d) *Rhodospirillum* is photosynthetic bacteria.
8. (c) *Nostoc*, *Chara*, *Porphyra* and *Wolfia* are Photoautotrophs while *Nitrosomonas* and *Nitrobacter* are chemoautotrophs

13. (b) In  $G^+$  (Gram-positive bacteria) cell wall is 200–300 Å thick having mucopeptides 85% and lipids 1–2% while in  $G^-$  (Gram-negative bacteria) cell wall is 100–200 Å thick and mucopeptides are 10–12% and lipids 80–90%.
23. (c) *E. coli* is a prokaryotic bacterium.
25. (a) Anaerobic breakdown of proteins is known as putrefaction.
29. (c) In many bacteria (specially gram +ve) the plasma membrane gives rise to infoldings called mesosome. They have respiratory enzymes like succinic dehydrogenase, cytochrome oxidase for respiration.
33. (a) The bacterial flagellum is long, filamentous and protoplasmic appendage that arise in the cell envelope. In the bacterial flagella instead of 9 + 2 arrangement of tubulin there is simply a single filament of globular protein called flagellin.
39. (d) Nitrifying bacteria such as *Nitrosomonas* and *Nitrobacter* manufacturing their organic food utilizing chemical energy in oxidation of some inorganic compound. Hence these bacteria are chemosynthetic.
40. (a) Branched chain lipids of cell membranes of archaebacteria enable them to tolerate high temperature and high acidity.
44. (b) During unfavourable condition highly resistant single spore is formed in the bacterial cell (e.g., Tetanus and anthrax bacteria) which is known as endospore.
52. (d) The bacterium *E. coli* have double stranded circular DNA. Many genetical researches are carried out on *E. coli* for the study of genetic engineering.
55. (a) Fimbriae are more in number, short thin straight bristle like appendages which function as organ of adhesion. Pili are similar to fimbriae but different in function.
59. (d) R-factor is type of plasmid which contains genes for antibiotic resistance.
67. (c) Respiratory enzyme containing infolding of plasma membrane in bacteria called chondrioid.
72. (d) The cell envelope in bacteria consists of a tightly bound three layered structure i.e. the glycocalyx followed by the cell wall and then plasma membrane.
75. (c) Cell membrane of archaebacteria possesses branched chain lipids.
76. (b) Mesosomes help in respiration, secretion processes, to increase the surface area of the plasma membrane and enzymatic contact.

77. (a) Bacterial cell wall is made of peptidoglycan.  
78. (c) Methanogens, halophiles and thermoacidophiles are archaeobacteria.

### Life cycle/Reproduction in bacteria

1. (a) The number of bacteria becomes double after each division.  
4. (a) In the process of transduction, virus is used as a carrier in the transfer of DNA from one bacterial cell to other.  
7. (d) Temperate phages are the avirulent lysogenic phages whose nucleic acids get incorporated in the bacterial DNA (lysogenization). When these phages infect bacteria, the bacterial cell undergoes many divisions and prophages are formed.  
9. (a) The phage  $\lambda$  DNA attaches to the specific site of bacterial genome with the help of  $\lambda$  integrase enzyme. The phage DNA in this latent (non virulent) form is called provirus or prophage (integrated viral DNA with the host bacterial DNA).  
19. (a) During conjugation two bacteria cell comes together and formed a conjugation tube. By this tube genetic material reach from donor to recipient bacteria.  
20. (a) Sex factor or F-factor are extra-chromosomal DNA particles which either integrate with main DNA or remain independent from main DNA.  
22. (b) It takes place by transferring DNA from capsulated to non-capsulated.  
17. (b) In this process bacteria decompose the pectin of the plant to liberate fibres. The process of fibre preparation is known as retting. This process is carried out by *Clostridium butyrium*.  
18. (b) Some bacteria such as *Thiobacillus denitrificans*, *Pseudomonas aeruginosa* and *Micrococcus denitrificans* also occur in the soil which convert the nitrate and ammonia into atmospheric free elemental nitrogen.  
20. (c) Actinomycetes are filamentous bacteria, inhabitant of soil. The genus *Frankia* causes nitrogen fixing nodules to form in older tree roots (non-legume plants).  
21. (a) Non-symbiotic nitrogen fixation takes place by Blue-green algae (*Nostoc* and *Anabena*) and free living soil bacteria (the aerobic *Azotobacter* species and the anaerobic *Clostridium* species).  
23. (c) Methanogens are archaeobacteria abundant in cattle yard and paddy fields.  
27. (c) They lack heterocyst. That is why, they can not take part in  $N_2$  fixation.  
28. (b) Non-symbiotic bacteria are also called free-living nitrogen fixing bacteria e.g. *Azotobacter*. They are agriculturally important.  
29. (b)  $NH_4 \xrightarrow{\text{Nitrosomonas}} NO_2 \xrightarrow{\text{Nitrobacter}} NO_3$ .

### Economic importance of bacteria

1. (d) *Spirulina* is SCP rich in protein, vitamins and minerals and rice variety rich in iron content. 250 gram biomass of *Methylophilus methylotrophus* produce 25 ton protein/day while cow of 250 Kg produces only 200gm protein/day  
2. (d) *Clostridium* is saprophytic, anaerobic  $N_2$  fixing bacteria and have ability to fix atmospheric  $N_2$  into  $NH_3$ .  
3. (b) *Azotobacter* (aerobic) is a free living  $N_2$ , fixing bacteria. This bacteria fix independently atmospheric nitrogen in their body and convert to organic nitrogen compounds. When they die, the organic nitrogen compounds of their body are made available to higher plants through the activities of other bacteria.  
4. (c) Bacteria causes  $N_2$  fixation.  
5. (c) *Anabaena cycadae* is a BGA found in coralloid roots of *Cycas*.  
6. (c) Bacteria causes the curing of tea and coffee by which bitterness is removed and flavour is added.  
33. (d) The main role of bacteria is as a decomposer. The bacteria decompose the complex organic compounds into simple one which are reused in carbon cycle.  
34. (a) Rhodospirillum bacteria is facultative aerobic photo-autotrophic bacteria use non-sulphur aliphatic organic compound as donor of  $H_2$  e.g., Propyl alcohol.  
$$6CO_2 + 12CH_3CHOHCH_3 \xrightarrow{\text{Light}} C_6H_{12}O_6 + 12CH_3COHCH_3 + 6H_2O$$
  
35. (c) LHB is  $O_2$  scavenger.  
39. (a) *Frankia* is a filamentous  $N_2$ -fixing bacteria which is symbiont on the root of *Casuarina equisetifolia*

**Bacterial diseases**

1. (b) On the basis of his work Pasteur proposed "germ theory of disease" which was recognised by medical scientists very soon.
6. (d) *Mycobacterium tuberculosis* releases the mycolic acid, it is changed to mycoides involved in causing disease.
7. (c) Tetanolysin is a Neurotoxins.
15. (b) Bacteria *Bacillus anthracis* caused anthrax disease.

**Mycoplasma**

2. (b) Little leaf of brinjal : In this disease, the leaves of Brinjal remain small in size because mycoplasma inhibits leaf expansion of leaf cells.
4. (d) Mycoplasma can grow outside the host cell. Thus it is clear that mycoplasma are not obligate parasite like viruses.
6. (a) Penicillin and vancomycin inhibits the cell wall synthesis.
10. (c) Elementary bodies are related with asexual reproduction of mycoplasma. When cell of mycoplasma divides into minute bodies, these bodies are called elementary bodies.
11. (b) Because mycoplasma lacks cell wall where as penicillin acts on cell wall.
14. (c) *Cuscuta reflexa* (Dodder) is parasite on angiosperms through which viruses and mycoplasma transmit.
16. (b) Mycoplasma lacks cell wall, therefore the outermost existing layer is cell membrane.
19. (c) *Mycoplasma salivarium* inhibit the food as well as blood to the developing embryo in pregnant female, which cause abortion.
22. (b) Mycoplasma is irregular in shape and divides by simple binary fission.
23. (b) Mycoplasma are cell wall less cells but show multiplication like bacteria, so that they are termed as cell wall less bacteria.
24. (d) Both mycoplasma and L-form bacteria are cell wall less.
25. (a) Due to the absence of cell wall, mycoplasma are highly elastic and readily change the shape, hence the mycoplasmas are irregular and quite variable in shape. This nature is called pleomorphism.

**Cyanobacteria / Blue green algae**

1. (d) Cyanobacteria have a water soluble phycobilin pigments *c*-phycocyanin (blue) and *c*-phycoerythrin (red).
2. (c) Myxophyceae is another name of cyanobacteria which are moneran.

3. (c) Each heterocyst is connected with vegetative cells, on two sides through the prominent pores into the wall. Which later on one occupied by a refractive cyanophycin granule called polar nodule.
4. (c) Chlorophyll-b is found in eukaryotic photoautotroph.
5. (a) *Nostoc* possess special type of cells called heterocyst for free  $N_2$  fixation that is why *Nostoc* is biofertiliser.
9. (a) Heterocysts are airtight anaerobic bodies in which enzyme nitrogenase fixes atmospheric nitrogen.
14. (c) Cilia and flagella absent in blue green algae.
19. (d) *Sinorhizobium* is a bacterium.
20. (d) Blue green algae or cyanobacteria is designated as Prokaryotes.
21. (d) *Spirulina* is a rich source of proteins and vitamin B-complex as well.
23. (b) Because they have photosynthetic lamellae for photosynthesis and heterocyst for  $N_2$ -fixation.
26. (c) *Anabaena* is found symbiotically in *Azolla* and help in  $N_2$  fixation.
27. (a) Cyanobacteria is haploid so meiosis and fertilization is absent.
31. (d) Because *Nostoc* is prokaryotes
33. (c) Cyanobacteria appeared in precambrian period around 3.2 billion years ago and were the first to have oxygenic photosynthesis to evolve  $O_2$  in photosynthesis that caused conversion of primitive reducing atmosphere to present day oxidising atmosphere (oxygen revolution).
42. (c) Unicellular forms reproduce asexually by binary fission while filamentous forms are by Homogones.
43. (c) Some cyanobacteria possess heterocyst like *Nostoc*, *Scytonema* etc. Heterocyst is a site of  $N_2$  fixation.

**Critical Thinking Questions**

2. (b) Mycoplasma are sensitive to tetracycline and resistant to penicillin, because they lack cell wall.
4. (a)  $K_{12}$  plasmid was first studied in *E.coli*, by two American scientist Lederberg and Tatum (1946).
5. (b) Lysozyme is an enzyme which can dissolve the cell wall of bacteria.
7. (a) Genetically modified *Pseudomonas* can decompose organic product like petroleum, oils etc.
9. (d) Chemosynthetic autotrophs oxidize inorganic substances to produce energy and helps cycling of minerals.
10. (c) Porins is a proteins, which is found in the cell of Gram negative bacteria. Which function as channels for the entry and exist of hydrophilic low molecular weight substances.

12. (d) As we know that bacterium divides after every 35 minutes through simple mitotic division therefore number of divisions are  $\frac{175}{35} = 5$

Since one bacterium on division produces two cells so cell concentration after 175 minutes will be

$$= 10^5 \times (2)^5 = 32 \times 10^5.$$

16. (d) Motile bacteria have thin filamentous extensions from their cell wall called flagella.
20. (c) Large central vacuole is present in plant cells
21. (c) Motility is performed by flagella only in bacterial cells while fimbriae provide attachment to base and pili form conjugation tube during conjugation

### Assertion and Reason

1. (a) Bacterial cell is prokaryotic. It lacks true nucleus, membrane bound organelles and sexual reproduction.
2. (b) Bacteria have different shapes spherical, rod, and spiral are three important type. Cocci may be in cluster or chain form or single and bacilli may be single, in pair in chain.
3. (b) Bacteria utilize the wavelengths longer than 700 nm for photosynthesis and the reaction centre is P-890 the reductant is  $\text{NADH} + \text{H}^+$ . In bacteria donor may be  $\text{H}_2\text{S}$  or malate or succinate.
4. (a) *Rhizobium* form a symbiotic association with roots of leguminous plants producing root nodules. These bacteria reside inside the nodules and reduce atmospheric nitrogen ( $\text{N}_2$ ) to ammonia. The fixed nitrogen is taken up by plant. In return the plant provides nutrients both and protection to bacteria.
5. (a) Plant cells are characterized by the presence of a rigid cell wall on the basis of which they can be differentiated from animal cells. Hence classified among plants.
6. (b) Myxobacteria do not have flagella and move by gliding movement.
7. (c) The cell wall of Gram-negative bacteria contains alcohol-soluble lipid, while the cell wall of Gram-positive bacteria lacks the lipids and therefore resist decolourisation and retain the primary stain, appearing violet. Gram-negative bacteria are decolorized by organic solvents and therefore, take the counter stain, appearing red. Gram +ve bacteria does not attracted towards positive pole under influence of electric current.
8. (d) Chemosynthetic bacteria are without photosynthetic pigments. For the synthesis of their own organic food, (carbohydrates), they obtain carbon from  $\text{CO}_2$  of the atmosphere, necessary energy from oxidation of inorganic or organic compounds, such as hydrogen sulphide ( $\text{H}_2\text{S}$ ), ferrous compounds ( $\text{Fe}^{2+}$ ), molecular hydrogen ( $\text{H}_2$ ) ammonia ( $\text{NH}_3$ ) and nitrites ( $\text{NO}_2^-$ ).
9. (a) Mostly pathogenic gram +ve bacteria releases exotoxins outside the cell and kills the W.B.C. and causes the disease.
10. (c) The bacteria play an important and dual role by disposing off the dead bodies and wastes of organism and by increasing the fertility of soil.
11. (a) Streptomyces produced broad spectrum of antibiotics by living microorganism capable of inhibiting or destroying other many types of microbes.
12. (d) Chemically bacteria consists of acetylglycosamine, acetyl muramic acid and a peptide chain of four or five amino acids. All these chemicals together form a polymer called peptidoglycan (= murein or mucopeptide). Some other chemical substances deposited on the cell wall are - teichoic acid, protein polysaccharides lipoproteins and lipopolysaccharides.
13. (a) *Anabaena* found symbiotically in the root nodules of many leguminous plants which helps in  $\text{N}_2$  fixation.
14. (a) *Bacillus butschli* is the Gram positive bacterium and its cell wall consist of acetyl muramic acid.
15. (c) In addition to bacterial chromosomes many bacteria have accessory rings of DNA called plasmids. Plasmids are absent in eukaryotic chromosome.
16. (e) In some bacteria, nonmotile appendages called pili or fimbriae are also present. They take part in sexual reproduction, i.e., conjugation.
17. (e) Cell secretion occurs even in the prokaryotic cells (bacteria) in relation to the production of a variety of enzyme to the medium. In certain protozoa, vacuoles similar to the contraction expel water into the medium. Golgi complex are found, which by their contraction expel water into the medium. Golgi complex and other membrane found organelle are absent in prokaryotes.
18. (a)

## Monera (Prokaryotes)

## ET Self Evaluation Test

- Which of the following represents obligate anaerobes  
(a) *Spirogyra* (b) *Pisum sativum*  
(c) Onion (d) Methane bacteria
- Mycoplasma mycoides* causes which of the following diseases  
(a) Bovine pleuropneumonia (b) Inflammation of genitals  
(c) Agalactia (d) None of these
- Food material can be preserved at [MP PMT 2006]  
(a) High temperature (b) Osmotic pressure  
(c) Low temperature (d) All of the above
- The bacteria which lacks flagella and moves by gliding are included in  
(a) Spirochaetes (b) Rickettsia  
(c) Myxobacteria (d) Eubacteria
- Select the correct match  

A.	<i>Nitrosomonas</i>	-	Nitrite to nitrate
B.	<i>Thiobacillus</i>	-	Denitrification
C.	<i>Nostoc</i>	-	Free-living nitrogen-fixer
D.	<i>Azotobacter</i>	-	Anaerobic nitrogen-fixer

[Kerala PMT 2011]

(a) A and B (b) C and D  
(c) B and C (d) B and D  
(e) A and C
- Pasteurization is heating at [MP PMT 2006  
DUMET 2009; CPMT 2009]  
(a) 120°C for 60 minutes (b) 60-70°C for 30 minutes  
(c) 70°C for 60 minutes (d) 80°C for 30 minutes
- Exotoxin is produced by  
(a) Gram positive bacteria (b) Gram negative bacteria  
(c) Both (a) and (b) (d) None of the above
- Clover phyllody is caused by [MP PMT 2011]  
(a) Spirochaetes (b) Protoplasts  
(c) Spheroplasts (d) Mycoplasmas
- The murein found in bacterial cell is [CPMT 1998]  
(a) Derivative of protein  
(b) Derivative of fat  
(c) Derivative of organic acids  
(d) Derivative of sugars
- Koch's postulates are not applicable to [CBSE PMT 1999]  
(a) T. B. (b) Leprosy  
(c) Cholera (d) Diphtheria
- The purple sulphur bacteria use hydrogen sulphide and release sulphur but not oxygen. Which of the following agrees with above observation [AIIEE Pharmacy 2002]  
(a) The  $H_2$  that reduces  $CO_2$  comes from  $H_2S$  that liberates sulphur  
(b) Photosynthesis does not require chlorophyll  
(c) Photosynthesis consist of a light and a dark reaction  
(d) The  $H_2$  which reduces  $CO_2$  in photosynthesis comes from  $H_2O$  that releases  $O_2$
- Why bacteria do not survive in the salt pickle which has high salt contents [KCET 2000]  
(a) Salt retards the rate of reproduction of bacteria  
(b) Bacteria do not get light for photosynthesis  
(c) Due to plasmolysis bacteria die  
(d) Essential elements for bacterial viability are not present in the pickle
- For reproduction, 'endospores' are formed in the following genera [BHU 1994; KCET 1999; Pb. PMT 2000]  
(a) *Bacillus* and *Clostridium*  
(b) *Mucor* and *Bacillus*  
(c) *Monococcus* and *Clostridium*  
(d) *Saccharomyces* and *Clostridium*
- Match column I with column II and select the correct option given below  

	Column I		Column II
A.	Aerobic	1.	<i>Frankia</i>
B.	Cyanobacteria	2.	<i>Azospirillum</i>
C.	<i>Casuarina</i>	3.	<i>Clostridium</i>
D.	Tropical grasses	4.	<i>Aulosira</i>
		5.	<i>Azotobacter</i>

[Kerala PMT 2006]

(a) A-4, B-3, C-2, D-1  
(b) A-3, B-5, C-4, D-2  
(c) A-2, B-1, C-3, D-5  
(d) A-5, B-3, C-4, D-1  
(e) A-5, B-4, C-1, D-2
- Which bacterium causes cotton destruction  
(a) *Clostridium botulinum*  
(b) *Spirochaeta cytophaga*  
(c) *Mycobacterium*  
(d) *Vibrio*
- Bacteroids are [MP PMT 2010]  
(a) Enlarged non-motile cellular bacteria *Rhizobium leguminosarum* in root nodules of legumes  
(b) A bacterial cell infected with viruses  
(c) A motile bacterium  
(d) *Nitrosomonas* bacteria in soil
- Activity of nitrogenase in nitrogen fixing micro-organisms can be seen when  
(a) Methane is converted to ethane  
(b) Ethane is converted to methane  
(c) Ethylene is converted to acetylene  
(d) Acetylene is converted or reduced to ethylene



18. *Azotobacter* and *Polymyxa* are example of [CBSE PMT 1996]

- Symbiotic nitrogen fixation
- Non-symbiotic nitrogen fixation
- Disease causing bacteria
- Ammonifying bacteria

19. Match the types of bacteria listed in column I with their activity given in column II. Choose the correct combination of alphabets of the two columns

Column-I (Types of bacterial)		Column-II (Activity)	
A.	<i>Streptomyces</i>	p.	Food poisoning
B.	<i>Rhizobium</i>	q.	Source of antibiotics
C.	<i>Nitrosomonas</i>	r.	Nitrogen fixation
D.	<i>Acetobacter</i>	s.	Nitrification
		t.	Vinegar synthesis

[NCERT; KCET 2004]

- A = q; B = r; C = p; D = t
- A = q; B = r; C = s; D = t
- A = s; B = t; C = p; D = r
- A = t; B = p; C = r; D = s

20. The bacteria *Pseudomonas* is useful because of its ability to [AIIMS 2004]

- Transfer genes from one plant to another
- Decompose a variety of organic compounds
- Fix atmospheric nitrogen in the soil
- Produce a wide variety of antibiotics

21. Pullorum disease of poultry is caused by [KCET 2000]

- Hemophilus*
- Clostridium*
- Salmonella*
- Mycobacterium*

22. Which of the following is a seed borne disease [DPMT 2004]

- Bacterial blight of rice
- Kharia of paddy
- Whiptail of Brassica
- All of these

3. (d) Food preservation and spoilage of food involve the factors that control the growth of microorganisms. These methods of preservation are used today.

1. **Osmotic pressure**—The addition of salts of a solution resulting in increase of osmotic pressure and can be used to preserve food. The high salt or sugar concentration draw water of any microbial cell out thus prevent their growth.

2. **Low-temperature**—Pathogenic bacteria with a few exception will not grow at low temperature (near about 0°C).

3. **Pasteurization**—It is heating of food at high temperature i.e., the microorganisms eliminated from the food.

4. (c) Cyanobacteria are also called myxobacteria. In which flagella one completely absent but the movement occurs in some genera by special gliding motion. Such movement are connected with the secretion of mucilage.

6. (b) In the classic pasteurization treatment of milk, the milk was exposed to a temperature of about 63°C for 30 minutes. Most milk pasteurization today uses higher temperatures, at least 72°C, but for only 15 seconds.

7. (a) Exotoxin is produced by mostly gram positive bacteria, these are proteinaceous and heat labile compound which are excreted by bacteria outside the cell.

9. (d) The mucopeptide or murein is a polymer of two amino sugars namely N-acetylglucosamine (NAG) and N-acetyl muramic acid (NAM).

10. (b) Causing agent of *Mycobacterium laprae* can not be cultured.

11. (a)  $6\text{CO}_2 + 12\text{H}_2\text{S} \xrightarrow{\text{Light}} \text{C}_6\text{H}_{12}\text{O}_6 + 12\text{S} + 6\text{H}_2\text{O} + \text{energy}$ . Here  $\text{H}_2\text{S}$  is utilized as a source of hydrogen, which reduces  $\text{CO}_2$  into glucose. Oxygen is not liberated in bacterial photosynthesis.

12. (c) Salting of pickles, meat, fishes etc. and addition of sugar to jams, jellies, cut fruits etc., prevent their decay by microbes, as the latter get killed due to plasmolysis or due to high concentration of salt or sugar.

13. (a) Endospore formation is more common in rod shaped bacteria or bacillus forms.

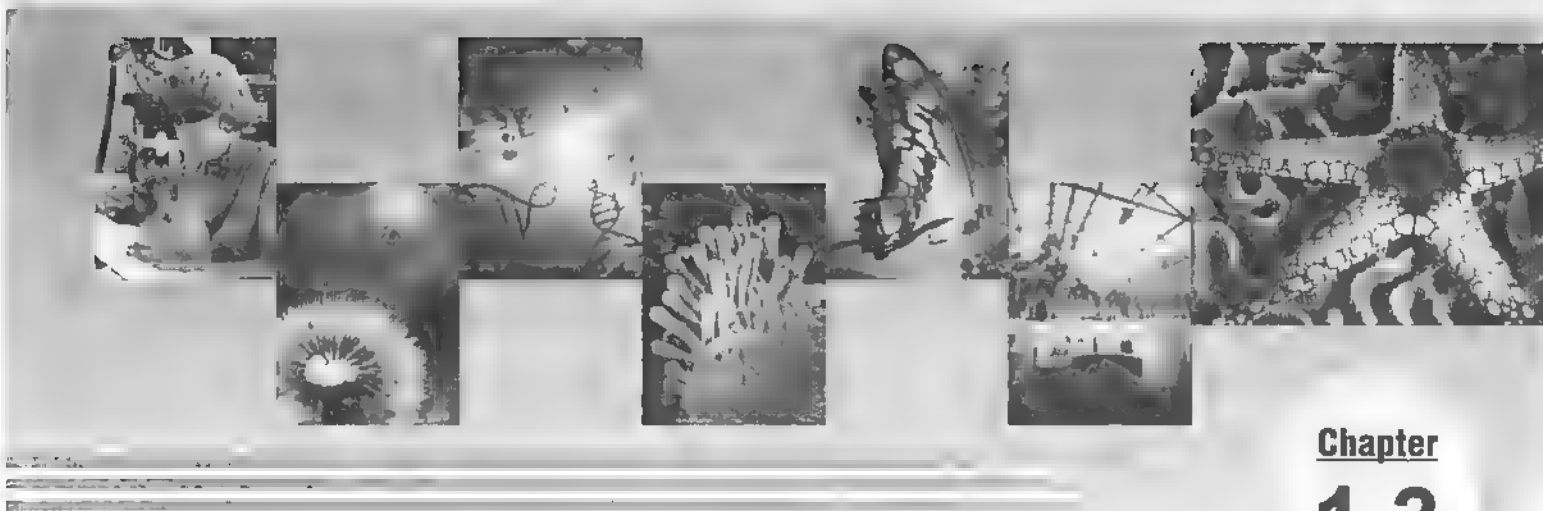
15. (b) Some bacteria damage cellulose of textiles. e.g., *Spirochaete cytophage*, *cellulomonas* etc.

16. (a) **Bacteroid** : Symbiotic bacteria *Rhizobium leguminosarum* in leguminous plants e.g., gram, pea etc. in their roots nodules produce *Leg haemoglobin*, this whole *Bacteria + Leg haemoglobin + Polyploid cells of roots* is called as bacteroid

22. (a) Bacterial blight of rice is a seed borne disease which is transmitted to paddy. Seedlings when raised under high humid conditions. This disease is caused by *Xanthomonas oryzae*.

## AS Answers and Solutions

1	d	2	a	3	d	4	c	5	c
6	b	7	a	8	d	9	d	10	b
11	a	12	c	13	a	14	e	15	b
16	a	17	c	18	b	19	b	20	b
21	c	22	a						



## Chapter 1.3

# Protista (Unicellular eukaryotes)

### Characteristics of protista

Protista (*Protistos* = Primary) includes unicellular eukaryotes and show the following characters :

(1) Protists include solitary unicellular or colonial unicellular eukaryotic organisms which do not form tissues.

(2) The single cell may be naked or covered by cell wall, pellicle, cuticle or shell.

(3) Simple multinucleate organisms or stages of life cycles occur in a number of groups.

(4) The organisms possess double and porous nuclear membranes, mitochondria, golgibody, plastids (in many), vacuoles, lysosomes and ribosomes are also present. Centrosome occur in many cases.

(5) In many forms, plastids, (9+2 strand) flagella and other organelles are present.

(6) Some protists possess contractile vacuole for regulation of their water content.

(7) Their reproductive cycles typically include both asexual divisions of haploid forms and true sexual processes with karyogamy and meiosis.

(8) The organisms move by flagella or by other means or are non-motile.

(9) It may be photosynthetic, holotrophic, saprotrophic, parasitic and symbionts. Some have mixotrophic nutrition (holotrophic + saprobic). The photosynthetic, floating protists are collectively called **phytoplankton**. The free-floating, holozoic protozoans are collectively termed **zooplankton**.

(10) Asexual reproduction is the most common method in protists. It involves binary fission (*Paramecium*, *Euglena*, *Amoeba*), multiple fission (*Amoeba*), plasmotomy (*Opalina*), budding (*Paracinetia*, *Arcella*) and spore formation (Slime moulds).

(11) Sexual reproduction is believed to have originated in primitive protists. It involves isogamy (*Monocystis*), anisogamy (e.g., *Ceratium*) and oogamy (e.g., *Plasmodium*).

**Classification of protista** : Unicellular protists have been broadly divided into three major groups :

(i) Photosynthetic protists : e.g., Dinoflagellates, Diatoms, Euglenoids.

(ii) Consumer protists : e.g., Slime moulds or Myxomycetes.

(iii) Protozoan protists e.g., Zooflagellata, Sarcodina, Sporozoa, Ciliata.

### Photosynthetic protists

#### Dinoflagellates

#### General characters

(1) This is a well defined group of unicellular, golden-brown photosynthetic organisms. Majority of them are motile and flagellated but a few are non-motile and non-flagellated. Flagellated forms exhibit peculiar spinning movement. Hence, they are called **whorling whips**.

(2) The cell wall of dinoflagellates, if present, is composed of a number of plates made up of cellulose. It is called **theca** or **lorica**. The theca contains two grooves-longitudinal **sulcus** and transverse **girdle** or **annulus**.

(3) Usually the cells possess two **flagella** which are of different types (heterokont).

(4) Trichocysts are rod like or spindle shaped ejective structures which occur just below the cell membrane.

(5) Cells possess a relatively large and prominent nucleus known as **mesokaryon**. DNA is without association with histone.

(6) There are numerous discoid chloroplasts without pyrenoids. They are yellow-brown to dark-brown in colour due to presence of characteristic **pigments** – Chlorophyll *a*, *c*,  $\alpha$ -carotene and xanthophylls (including dinoxanthin and peridinin).

(7) The cells possess an osmoregulatory organelle called **pusule** which superficially looks like contractile vacuole.

(8) In dinoflagellates it is mainly holophytic or photosynthetic. However, some forms are saprobic, parasitic, symbiotic or holozoic. For example, a colourless *Blastodinium* is parasite on animals.

(9) Dinoflagellates reproduce asexually through cell division or by the formation of zoospores and cysts. The cell division starts from posterior end. During cell division, centromeres and spindle are not seen.

(10) If sexual reproduction occurs, is isogamous or anisogamous. Two cells conjugate by a conjugation canal where the two amoeboid gametes fuse to form a diploid zygote. Life cycle involves zygotic meiosis (e.g., *Ceratium*, *Gymnodinium* etc.) or gametic meiosis (e.g., *Noctiluca*).

Examples : *Glenodinium*, *Peridinium*, *Gymnodinium*, *Gonyaulax*, *Ceratium*, *Noctiluca*.

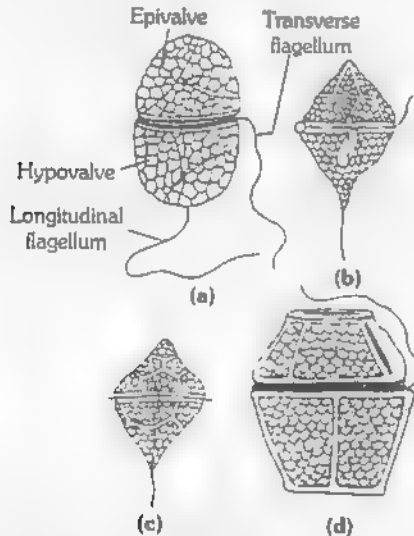


Fig : 1.3-1 Some dinoflagellates (a) *Glenodinium* (b) *Peridinium* (c) *Gymnodinium* (d) *Gonyaulax*

### Diatoms

#### General character

(1) Most of the diatoms occur as **phytoplanktons** both in fresh and marine waters. A few forms occur as benthos the bottom of water reservoirs. Diatoms constitute a major part of phytoplankton of the oceans.

(2) The cells of diatoms are called **frustules** or shell. They are microscopic, unicellular, photosynthetic organisms of various

colours and diverse forms. They may be circular, rectangular, triangular, elongated, spindle-shaped, half-moon shaped, boat-shaped or filamentous. Incipient filament occur in *Melosira*.

(3) They exhibit mainly two types of symmetry-radial symmetry as in **centrales** (e.g., *Cyclotella*, *Biddulphia*, *Triceratium*, *Melosira*) and isobilateral symmetry as in **Pennales** (e.g., *Pinnularia*, *Synedra*, *Actinella*, *Navicula*).

(4) The cell wall is chiefly composed of cellulose impregnated with glass-like silica. It shows sculpturings and ornamentations. It is composed of two overlapping halves (or theca) that fit together like two parts of a soap box. The upper half (lid) is called **epitheca** and the lower half (case) is called **hypotheca**.

(5) Diatoms do not possess flagella except in the reproductive stage. They show **gliding** type of movement with the help of mucilage secretion. They float freely on the water surface due to presence of light weight lipids.

(6) Each cell has a large central vacuole in which a prominent nucleus is suspended by means of cytoplasmic strands. The cells are **diploid** (2N). In case of centrales, the nucleus lies in the peripheral region.

(7) Some species of diatoms are devoid of chromatophores, e.g., *Nitzschia alba*. They are saprotrophic in nutrition.

(8) The reserve food material is **oil** and a polysaccharide – **chrysolaminarin** (or **leucosin**).

(9) Most common method of multiplication is **binary fission** (cell division) that occurs at night.

(10) Sexual reproduction takes place by the fusion of gametes. Meiosis is gametic i.e., takes place during the formation of gametes.

Examples : *Triceratium*, *Pleurosigma*, *Navicula*, *Cymbella*, *Amphipleura*, *Nitzschia*, *Melosira*, *Pinnularia*.

### Euglenoid

#### General characters

(1) Euglenoids and their non-motile relatives are unicellular flagellate protists.

(2) These protists are devoid of cellulose cell wall. The body is covered by thin and flexible pellicle. The pellicle has oblique but parallel stripes called **myonemes**. The pellicle is composed of fibrous elastic protein and small amount of lipid or carbohydrates.

(3) The euglenoids have two flagella, usually one long and one short. Each flagellum arises from a basal granule (blepharoplast). The flagella bear hair.

(4) They can undergo creeping through expansion and contraction of body called **metaboly**.

(5) The apical end bears an invagination having three parts—cytostome (mouth), cytopharynx (gullet or canal) and reservoir. The cytostome is generally eccentric.

(6) The two flagella join with each other at a swelling called paraflagellar body. An orange red coloured eye-spot or stigma is located at the base of flagellum attached to the membrane of reservoir at the level of paraflagellar body. They contain red pigment **astaxanthin**. Both paraflagellar body and eye spot act as photoreceptors and direct the organism towards the optimum light.

(7) An osmoregulatory contractile vacuole occurs in the anterior part of the cell below the reservoir.

(8) Nutrition is holophytic (photoautotrophic), saprobic (e.g., *Rhabdomonas*) or holozoic (e.g., *Peranema*). Even holophytic forms can pick up organic compounds from the outside medium. Such a mode of nutrition is called mixotrophic.

(9) Product of photosynthesis is paramylon which is stored in the form of paramylum granules in the paramylum bodies in cytoplasm.

(10) Sexual reproduction has not yet been definitely proved. Under favourable conditions, euglenoids multiply by longitudinal binary fission.

(11) These protists perennate during unfavourable periods as cysts.

Example : *Euglena*, *Phacus*, *Eutreptia*, *Trachelomonas*, *Peranema*.

### **Euglena**

#### **General characters**

- (1) *Euglena* is a connecting link between animals and plants.
- (2) *Euglena* resembles the ancestral form from which the plants and animals evolved.
- (3) *Euglena* is a free swimming fresh water flagellate which moves by two different methods :
  - (i) Euglenoid movement (wriggling movement), by contraction and expansion of the body.
  - (ii) Flagellar movement, with the help of sticonematic type flagellum.
- (4) Body is covered by pellicle, a small cytostome (cell mouth) and cytopharynx is present at the anterior end of the body.
- (5) *Euglena* contains chlorophyll, yet it resembles animals, because it feeds like animals in the absence of sunlight.
- (6) Nutrition in *Euglena* is mixotrophic, when light is available it is photosynthetic, in darkness it is saprophytic absorbing food from surrounding water.
- (7) Reserve food is stored in the form of paramylum or paramylon.
- (8) Asexual reproduction occurs by longitudinal binary fission, no sexual reproduction.

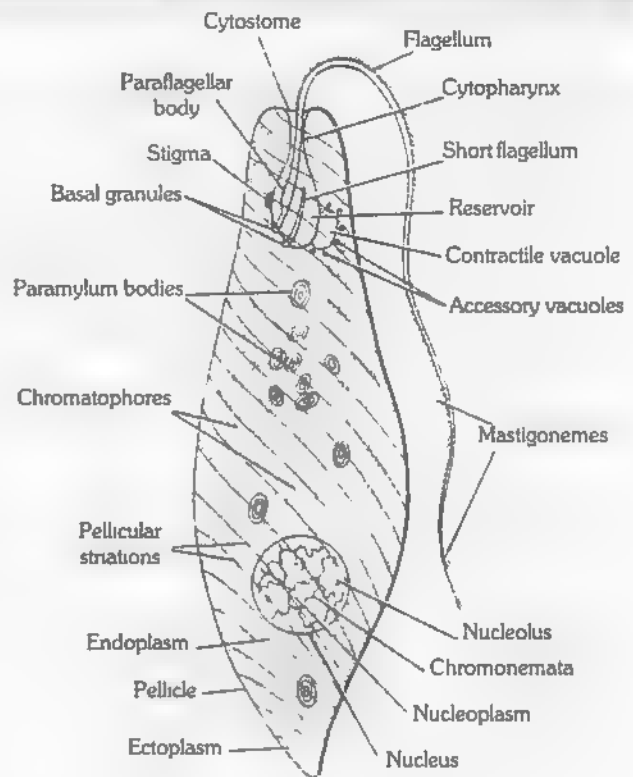


Fig : 1.3-2 *Euglena viridis*

## **Consumer / Decomposer protists**

### **Slime moulds**

Slime moulds include very interesting and peculiar organisms which share the characters of both animals and fungi. Due to this peculiarity they are commonly called **fungus animals**. Modern biologist include slime moulds under the kingdom-protista and called them protistan fungi.

#### **General characters**

- (1) They do not have chlorophyll.
- (2) They are surrounded by the plasma membrane only (somatic parts are without cell walls).
- (3) At one stage of the life cycle they have amoeboid structure.
- (4) The slime moulds live usually amongst decaying vegetation. They are quite common on lawns and moist fields.
- (5) They have phagotrophic or saprotrophic nutrition. Parasitic forms are not known.
- (6) The sporangia produce spores. Each spore possesses a cellulose cell wall.

### **Acellular (Plasmodial) Slime moulds**

#### **General characters**

- (1) Acellular slime moulds commonly grow as slimy masses on damp places rich in dead and decaying organic matter.
- (2) The somatic phase is diploid and consists of a free living organic matter multinucleated protoplasm called plasmodium.

(3) The plasmodium slowly streams or glides over decaying organic matter putting out blunt finger like pseudopodia showing amoeboid movement.

(4) They also absorb dissolved organic substances from the substratum showing saprotrophic nutrition.

(5) Each plasmodium reproduces asexually by the formation of several, small, sessile or stalked, brightly coloured sporangia.

(6) When fully mature, the wall of the sporangium bursts to release the spores. The spores are dispersed by air.

(7) On germination, a spore generally releases one biflagellate, spindle-shaped swarm cell or a non-flagellate myxamoeba. The myxamoebae feed on bacteria and yeasts and multiply in number. The swarm cells swim about actively and finally fuse in pairs at the posterior nonflagellate ends to form zygotes.

(8) The diploid nucleus of zygote undergoes repeated mitotic divisions. As a result, the zygote gradually changes into a multinucleate amoeboid structure, the plasmodium. The plasmodium repeats the life cycle.

Examples *Physarum*, *Physarella*, *Fullgo*, *Dictydium*, *Lucogala*, *Tubifera*.

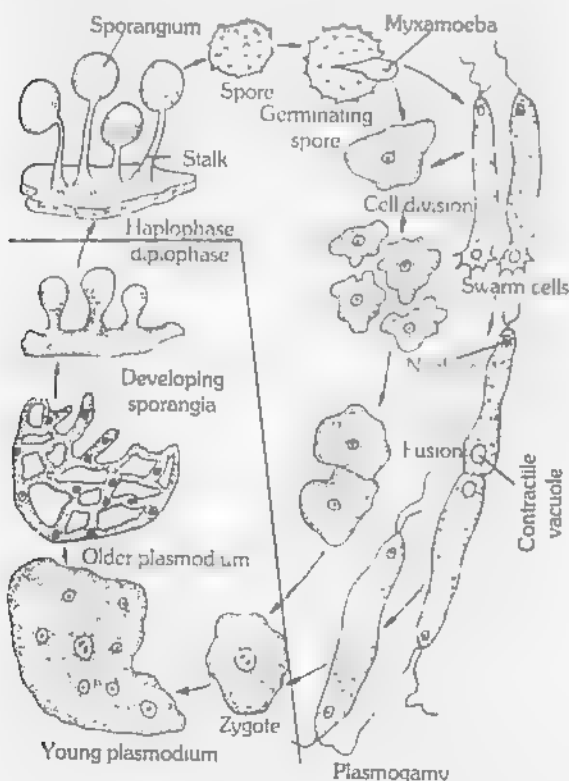


Fig : 1.3-3 Diagrammatic life cycle of acellular Slime mould (e.g., *Physarum*)

(3) Under unfavourable condition a myxamoeba secrete a rigid cellulose wall to form the microcyst. Microcyst formation is a means of perennation.

The microcysts can be dispersed. On the return of favourable conditions, the microcyst wall ruptures to release a myxamoeba. The latter resumes its function of feeding, growth and multiplication forming amoeboid cells.

(4) When the food supply is exhausted the amoeboid cells get aggregated without any fusion. The stimulus for the aggregation process is due to release of cyclic 3',5' adenosine monophosphate (cyclic AMP) from the amoeboid cells. This aggregated mass of cells is called pseudoplasmodium. It is a sort of community association. Because of this reason, cellular slime moulds are called the communal slime moulds.

(5) The stalk of sporocarp may remain upright or bend. Finally the spores are released and disseminated.

(6) The most important character of cellular slime moulds is the complete absence of flagellated cells in their life cycle.

(7) The cellular slime moulds resemble plant in having cellulose cell wall in spores and resemble animals in having amoeba-like myxamoebae.

Examples : *Dictyostellium*, *Polysphondylium*.

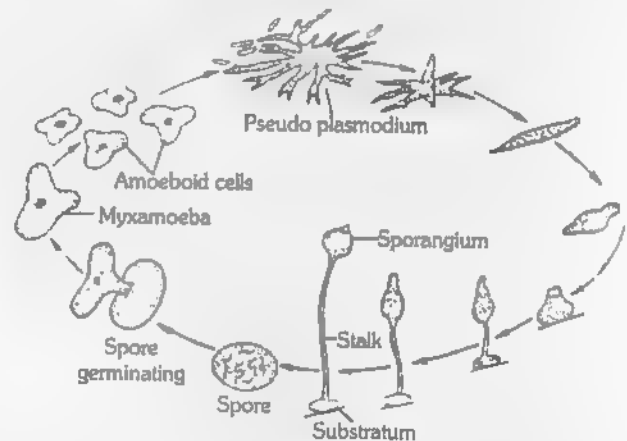


Fig : 1.3-4 Diagrammatic life cycle of cellular slime mould  
Protozoan protists (Gr. *Protos* = first ; *zoon* = animal)

It include all unicellular (or acellular) eukaryotic animals. These are most primitive organisms considered as animals because of heterotrophic nutrition and motility. About 50,000 species (30,000 present and 20,000 extinct) are so far known.

**Brief history :** Protozoans were first studied by Leeuwenhoek (1677). The name "Protozoa" was coined by Goldfuss (1817). The branch of their study is called Protozoology.

#### General characters

- (1) Protozoans are the simple and primitive organisms.
- (2) They are free living or parasitic.

### Cellular Slime moulds

#### General characters

(1) The cellular slime moulds occurs in the form of haploid uninucleated, naked (without cell wall) cell covered by plasma membrane. These cells are called myxamoebae.

(2) The myxamoebae move freely with the help of amoeboid movement and phagotrophic or holozoic nutrition.

(3) They are asymmetrical or radially symmetrical or bilaterally symmetrical.

(4) They are unicellular (acellular).

(5) They have protoplasmic grade of organization.

(6) Locomotion is effected by flagella, cilia or pseudopodia.

(7) Nutrition is holophytic, holozoic, saprozoic or parasitic.

(8) Digestion is intracellular.

(9) Excretion and respiration occurs by diffusion.

(10) In fresh water protozoans osmoregulation is carried out by the contractile vacuoles.

(11) Reproduction occurs by asexual and sexual methods.

### Classification of Protozoans

Protozoans are classified on the basis of locomotory organelles into following classes.

#### Class 1. Rhizopoda or Sarcodina

(1) There is no definite cell wall or pellicle.

(2) There is no definite shape.

(3) The locomotory organs are pseudopodia.

(4) There is no permanent mouth or anus.

(5) The contractile vacuoles are present in the fresh water forms.

The rhizopoda has been divided into five orders. They are as Lobosa, Filosa, Foraminifera, Heliozoa and Radiolaria.

Examples : *Amoeba*, *Entamoeba histolytica*, *Entamoeba coli*, *Pelomyxa*, *Globigerina*, *Actinophryx*.

□ In *Arcella* has an exoskeleton of tactin.

□ *Giardia* is called 'Grand old man of intestine'.

□ *Actinophryx* is called 'Sun animalcule' as it resemble the sun.

#### Class 2. Flagellata or Mastigophora

(1) The body is covered by a thin pellicle or cuticle.

(2) The locomotory organs are flagella.

(3) The contractile vacuoles are present in fresh water forms with accessory vacuoles.

(4) Chloroplast are found in some forms.

(5) They may be free living or parasitic.

The class flagellata has been divided into eight orders. They are as Chrysomonadina, Cryptomonadina, Euglenoidea, Phytomonadina, Dinoflagellata, Cystoflagellata, Protomonadina and Polymastigina.

Examples : *Chrysamoeba*, *Cryptomonas*, *Volvox*, *Chlamydomonas*, *Noctiluca*, *Mastigamoeba*, *Monal*, *Bado*, *Trypanosoma*, *Leishmania*, *Proterospongia* etc.

□ *Trychonymph* (symbiotic) live in alimentary canal of termite that is digest to cellulose.

□ *Noctiluca* shows bioluminiscense due to luciferin protein. It is also called the 'Fire of sea'.

#### Class 3. Sporozoa

(1) They are exclusively endoparasitic.

(2) The body is covered by pellicle.

(3) Reproduction takes place by spore formation.

The class is divided into two sub-classes, namely, Telosporidia and Neosporidia

##### Sub-class (i) Telosporidia

(1) The spores do not contain polar capsules or filaments.

(2) The life history ends with the formation of spores.

(3) The spore cases are simple and contain many spores.

Examples : *Monocystis*, *Gregarina*, *Isopora*, *Eimeria*, *Plasmodium*, *Babesia* etc.

□ *Babesia* causes the 'Texas cattle fever' in animals. This disease also called 'Red water fever' or Haemoglobin uric fever.

□ *Monocystis* is found in seminal vesicle of earthworm, and causes sterility in earthworm. It is monogenetic in nature.

□ *Eimeria* is found in epithelial cells of liver of Rabbit.

##### Sub class (ii) Neosporidia

(1) The trophozoite is amoeboid multinucleated.

(2) Spore cases are complex usually having a single germ.

Examples : *Nosema*, *Myxidium*, *Globidium* etc.

#### Class 4. Ciliophora

(1) The body is covered by thin pellicle.

(2) They have a fixed permanent shape.

(3) The locomotory organs are cilia.

(4) Tentacles are present.

(5) Nuclei are usually of two kinds micronucleus and meganucleus.

The class ciliophora is divided into two sub-classes, namely Ciliata and Suctorina.

##### Sub-class (i) Ciliata

(1) Cilia are present throughout life.

(2) Tentacles are absent.

(3) Mouth and cytopharynx are usually present. Cytoppyge is a temporary anal apperture.

(4) Contractile vacuoles are present.

(5) Trichocysts, organs of offense and defence are present in certain forms.

Examples : *Paramecium*, *Stylonchla*, *Vorticella* etc.

□ *Vorticella* is called 'Bell animalcule'. It is a pedicellate protozoan.

□ *Nyctotherus* is a parasite in the rectum of frog. It is also found in the rectum of cockroach.

##### Sub-class (ii) Suctorina

(1) Cilia are present only in the young conditions and adults are devoid of them.

(2) Tentacles are present in the adult.

(3) One to many contractile vacuoles are present.

Examples : *Acineta*, *Ephelota*, *Dendrocometes*, *Dendrosoma* etc.



## Some representative protozoan protists

### *Amoeba proteus*

#### General characters

- (1) *Amoeba* belongs to the class Sarcodina or Rhizopoda of the phylum protozoa. It is discovered by Russel Von Rosenhoff in 1755.
- (2) The most common species is *Amoeba proteus*. Proteus is the name of the mythical sea god who could change shape.
- (3) *Amoeba* is cultured in laboratory by Hay infusion method.
- (4) Body is covered by plasmalemma. It is a trilaminar and selectively permeable membrane. Plasmalemma is excretory, ammonia diffuses out through it. It is also respiratory diffusion of oxygen and carbon dioxide takes place through it.
- (5) The body bears a number of temporary and blunt pseudopodia. The type of pseudopodium found in *Amoeba proteus* is lobopodium. Pseudopodia are composed of both ectoplasm and endoplasm.
- (6) Pseudopodium at its forward end gets its firm consistency by hyaline cap which is made of ectoplasm.
- (7) Pseudopodia in *Amoeba* are meant for feeding and locomotion.
- (8) Pseudopodia are found in *Amoeba* and leucocyte of higher animals.
- (9) Cytoplasm is differentiated into outer ectoplasm and inner endoplasm. Endoplasm is divided into outer plasma gel and inner plasma sol.
- (10) Locomotion of *Amoeba* is known as amoeboid movement. Sol gel theory of amoeboid movement was first given by Hyman supported by Pantin and Mast. According to this theory amoeboid locomotion is due to change in the viscosity of cytoplasm. This is the most accepted theory.

Table : 1.3-1 Theories of Amoeboid Movement

Surface tension theory	Berthold	(1886)
Rolling movement theory	Jennings	(1904)
Walking movement theory	Dellinger	(1906)
Sol-gel theory	Hyman	(1917)
Folding and unfolding theory	Goldacre and Lorch	(1950)
Contraction-hydraulic theory	Rinaldi and Jahn	(1963)

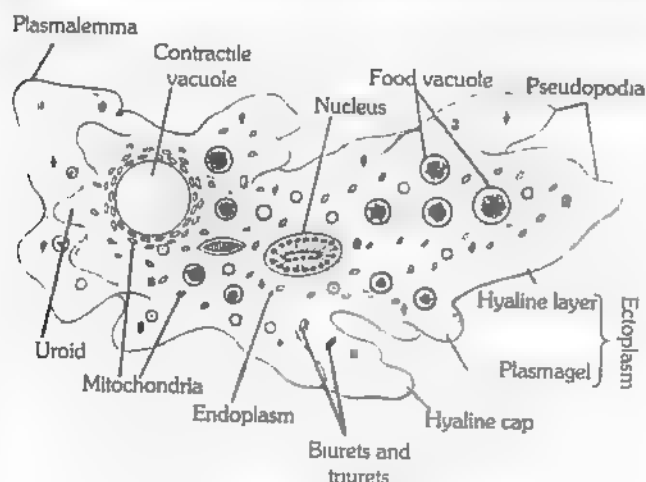


Fig : 1.3-5 Structure of *Amoeba proteus*

(11) Sol gel conditions are due to contraction and relaxation of long chains of proteins.

(12) *Amoeba* contains a nucleus, a contractile vacuole, a number of food vacuoles and other cell organelles.

(13) Vacuole is found only in fresh water forms. It is absent in marine and parasitic forms.

(14) If an *Amoeba* is placed in distilled water its contractile vacuole works faster while in salt water, its contractile vacuole will disappear.

(15) Contractile vacuole of *Amoeba* is analogous (similar in function) to uriniferous tubules of frog.

(16) Food of *Amoeba* consists of bacteria, diatoms, small protozoa and algae.

(17) The process of ingesting solid food is phagocytosis, *Amoeba* ingest food by import, circumfluence, circumvallation and invagination.

(18) Import involves passive sinking of food into body by rupture of plasmalemma, e.g., Ingestion of algae.

(19) Circumfluence is the ingestion of less active or motionless organisms like bacteria.

(20) Circumvallation is the engulfment of active prey like ciliate or flagellate. In this way a food cup is formed containing the organism.

(21) Digestion in *Amoeba* is intracellular. *Amoeba* secretes digestive enzymes for hydrolysing starch, protein, fat etc.

(22) Food vacuole of *Amoeba* is analogous to the alimentary canal of an animal or gastro vascular cavity of *Hydra*. The contents of food vacuole in *Amoeba* first becomes acidic then alkaline.

(23) *Amoeba* responds to environmental conditions. Response to the stimuli is called taxis. Different taxis are thermotaxis (temperature) phototaxis (light), thigmotaxis (touch), chemotaxis (chemicals), galvanotaxis (electric current), geotaxis (gravity) and rheotaxis (water current).

(24) Normal method of asexual reproduction is binary fission. Binary fission is a process of mitosis. It takes place when food is abundant and temperature is suitable.

(25) Multiple fission or sporulation takes place during unfavorable conditions after encystment. There are three layers of cysts.

(26) *Amoeba* regenerates from nucleated bits.

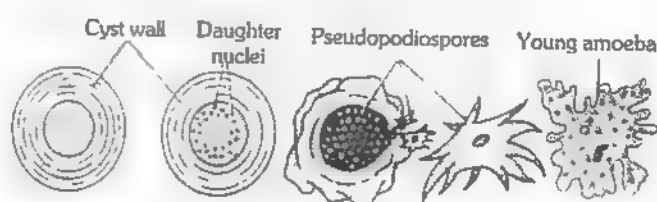


Fig : 1.3-6 Encystment and multiple fission in *Amoeba*

**Pseudopodia** : These are found in those forms which do not possess a definite pellicle. According to size, structure, and shape pseudopodia may be of different types as :

**Lobopods** : These are short, blunt and thick finger like out growth of ectoplasm with an axial core of endoplasm e.g., *Amoeba*, *Arcella* etc.

**Filopods** : They are cylindrical thread like, formed entirely of ectoplasm and radiate from the body in all directions e.g., *Euglypha*, *Radiolaria*.

**Reticulopods** : They are filamentous which form a network of pods e.g., *Polystomella*, *Chlamydomorphys*.

**Axopods** : These are long stiff semi-transparent extensions of cytoplasm with pointed distal ends e.g., *Actinophrys*.

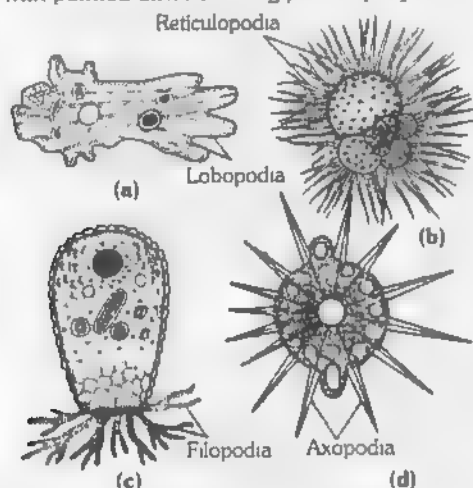


Fig : 1.3-7 Structure of Lobo, Filo, Reticulo and Axopods

### *Entamoeba histolytica*

#### General characters

(1) *Entamoeba histolytica* is a monogenetic parasitic and pathogenic protozoan protists which resides in the upper part of large intestine in human beings. It causes amoebic dysentery or amoebiasis.

(2) Lamble (1859) discovered *E. histolytica*. Friedrich Losch, a Russian Zoologist, discovered its pathogenic nature in 1875.

(3) It has two forms, adult trophozoite or magna, pathogenic form found in the mucosa and sub-mucosa of intestine forming ulcers and minuta, nonpathogenic form found in the lumen of intestine.

(4) *Entamoeba* has no contractile vacuole.

(5) Trophozoite of *Entamoeba* reproduces by binary fission. Minuta form encysts. A mature cyst is called quadrinucleate cyst. It has four nuclei and two chromatoid bodies

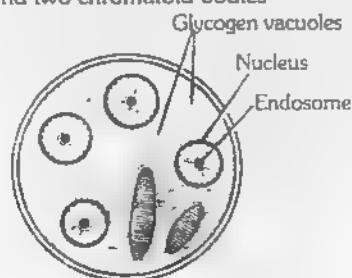


Fig : 1.3-8 Quadrinucleate cyst of *Entamoeba histolytica*

(6) Quadrinucleate cyst is the infective stage. Infection is oral through contaminated food and water.

(7) The reserve food material in cyst of *E. histolytica* is glycogen. A single cyst of *E. histolytica* produces eight amoebulae.

(8) It damages intestinal mucosa by secreting an enzyme-histolysin

(9) It completes its entire life-cycle in one host only; Man

### *Entamoeba gingivalis*

*Entamoeba gingivalis* is a parasite of human teeth, found in the abscesses of gum and in pus pockets of pyorrhoea, bleeding gums. It increase pyorrhoea disease but does not cause it. Pyorrhoea is caused by *Trichomonastinax*. Adult is called trophozoite and has 2-3 pseudopodia. It feeds on WBCs, bacteria and pus cells. Cyst is not formed in *E. Gingivalis* and infection occurs by direct contact like kissing.

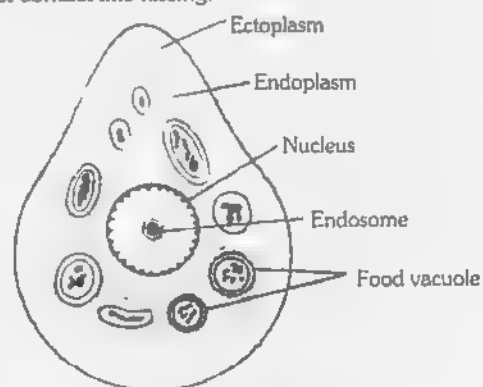


Fig : 1.3-9 *Entamoeba gingivalis*

### *Trypanosoma gambiense*

#### General characters

(1) *Trypanosoma gambiense* is the parasite zooflagellate which causes one of the deadliest ailments in human beings called African sleeping sickness or Trypanosomiasis. It was discovered by Frode in 1901.

(2) *Trypanosoma* is usually found in the blood of vertebrates, finally invading cerebrospinal fluid

(3) *Trypanosoma* is an endoparasite, blood parasite, extra cellular parasite.

(4) *Trypanosoma* has a nucleus, a flagellum, undulating membrane, blepharoplast (basal granule) and kinetoplast. The flagellum arises from the posterior end and runs anteriorly with undulating membrane.

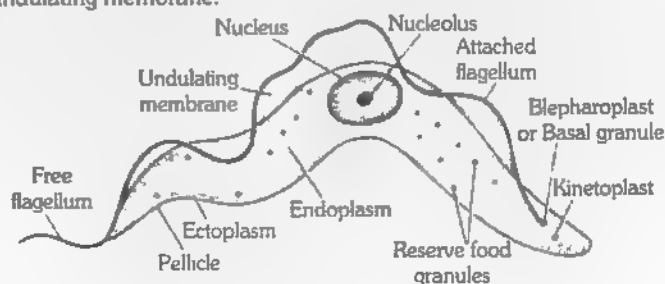


Fig : 1.3-10 *Trypanosoma gambiense*

(5) *Trypanosoma* reproduces asexually by longitudinal binary fission. It does not form cysts.

(6) *Trypanosoma* is polymorphic and has four forms: *Leishmania*, *Leptomonad*, *Crithidial* and *Trypanosomal* (= Metacyclic) stages.

(7) *Trypanosoma* is digenetic, it completes its life cycle in two hosts. The primary or principal or definite host is man and the intermediate or secondary host or vector is the insect, tse-tse fly or bug.

(8) Three important species of *Trypanosoma* for which man is host are : *Trypanosoma gambiense*, *T. rhodesiensi* and *T. cruzi*.

(9) The chief vector host of *T. gambiense* transmitting the disease from one man to another is the tse-tse fly, *Glossina palpalis*. Occasionally, *Glossina tachinoides* also act as a vector.

(10) *T. rhodesiensi* causes Rhodesian trypanosomiasis, it is confined to east central parts of Africa, particularly Rhodesia. The insect vectors for *T. rhodesiense* are tse-tse flies mainly *Glossina morsitans* and *G. pallidipes*.

(11) *T. cruzi* is the causative agent of South American trypanosomiasis or Chaga's disease *T. cruzi* is transmitted by bugs like *Triatoma* and *Panstrongylus*. Symptoms of Chaga's disease are fever, diarrhoea, anaemia and enlargement of lymphoid glands etc.

### ***Plasmodium vivax***

They are spore forming parasitic protists which lack locomotory structure and contractile vacuoles. The body is covered by pellicle or cuticle.

#### **Systematic position**

Phylum	–	Protozoa
Sub-phylum	–	Plasmodroma
Class	–	Sporozoa
Sub-class	–	Telosporidia
Order	–	Haemosporidia
Genus	–	<i>Plasmodium</i>
species	–	<i>vivax</i>

**History :** The term malaria was coined by Mucculoch in 1827

Lancisi first suspected a relationship between malaria and mosquito.

Laveran (1880) discovered that malaria is caused by a protozoan parasite, *Plasmodium vivax*.

Sir Ronald Ross was (1896) the first to observe oocytes of *Plasmodium* in female *Anopheles*.

Grassi and Feletti (1898) was the first to describe the life cycle of *Plasmodium* in *Anopheles*.

Golgi (1885) Studied erythrocytic cycle of plasmodium.

**Host :** It is digenetic i.e., life cycle is completed in two hosts –

(1) Man (medically primary but biologically secondary host)

(2) Female *Anopheles* (medically secondary but biologically primary host).

**Life cycle :** During life cycle two important phases are present.

(1) Endogenous or Asexual phase : passes in man.

(2) Exogenous or Sexual phase : passes in female *Anopheles* mosquito.

#### **In Man (Schizogony)**

**Infective stage :** It is spindle shaped sporozoite introduced by female *Anopheles* along with saliva (for anticoagulant anaphilin) during blood sucking. Sporozoite enters liver cells. In liver they produce several stages.

**Pre-erythrocytic stage :** Each sporozoite enters inside the liver cell and becomes spherical and termed as cryptozoite. It undergoes a pre-erythrocytic cycle completed in 10 days and multiplies asexually by schizogony. After rupturing schizont numerous cryptomerozoites are liberated.

**Exo-erythrocytic stage :** Cryptomerozoites enter in new liver cells and reproduce asexually to give rise to a large number of meta-cryptomerozoites, few are smaller in size and called micro-metacryptomerozoites.

**Erythrocytic stage :** Micro metacryptomerozoites enter into the blood stream and each enters the RBCs and assumes rounded disc like shape with single nucleus. It develops a vacuole which gives a ring like appearance. This stage is known as signet ring stage. During further development the vacuole is lost and parasite feeds on the cytoplasm of R.B.C. This stage is known as amoeboid stage or trophozoite stage. The matured trophozoite develops to become a schizont. It multiplies asexually by erythrocytic schizogony.

**Formation of gametes :** Some merozoites do not enter schizogony but instead form gametocytes in RBCs. Gametocytes are of two types :

(1) **Macro-gametocytes :** These are female cells which are large in size, laden with food material and having nucleus at one end.

(2) **Micro-gametocytes :** These are male cells, small in structure and nucleus placed centrally.

#### **In Mosquito (Sporogony)**

When female *Anopheles* bites a patient of malaria, the parasites enter the alimentary canal of the insect. In the stomach of mosquito the asexual forms are digested and only gametocytes survive. Gametocytes are released in blood plasma in large numbers during mid night. They die by morning. Megagametocyte produces only one megagamete. Microgametocyte produces 4-8 motile microgametes by exflagellation.

**Fertilization :** Both mega and microgamete fuse, form zygote which narrows to becomes ookinete. Ookinete pierces the stomach wall and forms a cyst on its outer surface.

**Sporogony :** Oocyst undergoes a process of sporogony. The irregular cells thus formed are known as sporoblasts. The nucleus of sporoblast divides several times to give rise to daughter nuclei which migrate in the projections of sporoblast.

These minute projections change into the form of sporozoites. After maturity oocyst burst out and numerous sporozoites are liberated into the body cavity of mosquito. The sporozoites move towards salivary glands and bore into them. In this way they are ready for transmission.

### Control of malaria

**(1) Prevention from infection is called prophylaxis.**

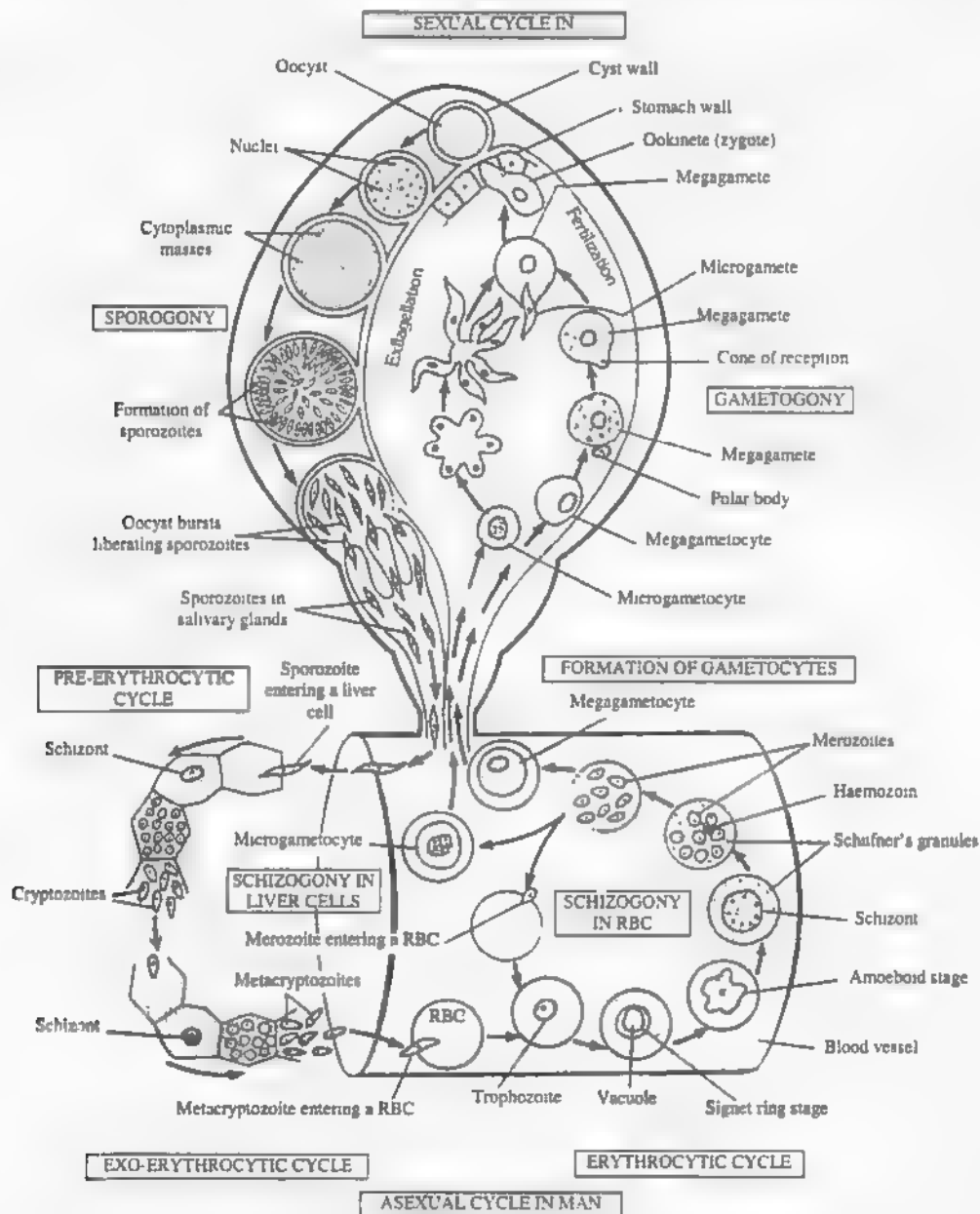
(2) Quinine is obtained from bark of *Cinchona* (discovered in Peru) which is most commonly used against malaria.

(3) Peludrine, atabrine, camoquinine, Chloroquinine are few other drugs effective against malaria.

(4) G.B.P. is General Blood Picture i.e., blood film made for the test of malaria.

(5) Spraying of oil upon stagnant water controls malaria because larva cannot breath and die.

(6) *Gambusia* (Mosquito fish) feeds on larvae and pupa of mosquito. This fish is used in biological control of mosquito.



**Fig : 1.3-11 Life cycle of *Plasmodium vivax***

Table : 1.3-2

Name	<i>P. vivax</i>	<i>P. malariae</i>	<i>P. ovale</i>	<i>P. falciparum</i>
1 Site	Liver and RBC of man	Liver and RBC of man	Liver and RBC of man	Liver and RBC of man
2 Distribution	Tropical countries subtropical	Tropical countries subtropical	West Africa and South America	Tropical countries
3. Duration of exoerythrocytic cycle or prepatent period	8 days	14-15 days	9 days	5 days
4. Duration of erythrocytic cycle	48 hours	72 hours	48 hours	48 hours
5 Incubation period	12-14 days	20-24 days	14 days	12 days
6 Duration of sexual cycle	10 days	26-28 days	16 days	10-12 days
7 Disease (Type of malaria fever)	Benign and tertian malaria / relapse malaria	Quartan malaria clinical malaria	Ovale and tertian recuris every third day	Malignant tertian malaria Pernicious malaria Estivoautumnal malaria
8 Pigment and color	Schuffner's granules Yellow / brown	Zeiman's dots Dark brown	Schuffner's dots Dark brown	Maurer's dots Dark green

### Paramecium

(1) *Paramecium* is a holotrichous ciliate protozoan. It is discovered by Hill in 1752.

(2) *Paramecium* is free-living and aquatic form. In laboratory, *Paramecium* is cultured by 'Hay-infusion method'.

(3) *Paramecium* is commonly called as 'Slipper animalcule'. Body is distinguished into an oral or ventral surface and an aboral or dorsal surface.

(4) Body is covered with a thin, firm, flexible membrane called pellicle. Entire body surface is covered by numerous cilia, the locomotory organelles. Cilia in the posterior end are longer called caudal tuft. Each cilium arises from a basal granule or kinetosome. *Paramecium* has infraciliary and neuromotor system to co-ordinate ciliary beat.

(5) Trichocysts are peculiar bottle-shaped organelles present in the ectoplasm of *Paramecium*. Trichocysts are the organelles of offence and defence.

(6) *Paramecium* is heterokaryotic (dimorphic nuclei) i.e., macronucleus and micronucleus. Macronucleus is one, large, kidney shaped, controls vegetative functions (metabolism). Micronuclei, one (*P. caudatum*), two (*P. aurelia*) and several (*P. multimicronucleatum*) are only concerned with reproduction.

(7) Oral apparatus consists of cytopharynx and cytostome (mouth), cytopye or cytoproct (anus). Nutrition or food intake in *paramecium* is holozoic. *Paramecium* is a filter feeder and feeds on small protozoa, unicellular plants (algae), diatoms, yeast etc. and small bits of animals and vegetables. Most favourite food is *Tetrahymena*, another ciliate protozoa.

(8) Digestion in *paramecium* is intracellular. Food vacuole constantly moves along a definite course (cyclosis) within streaming endoplasm. Food vacuole is digested in the cell body in acidic to alkaline media. Egestion of undigested food takes place through cytopye or cytoproct, a temporary formed anus.

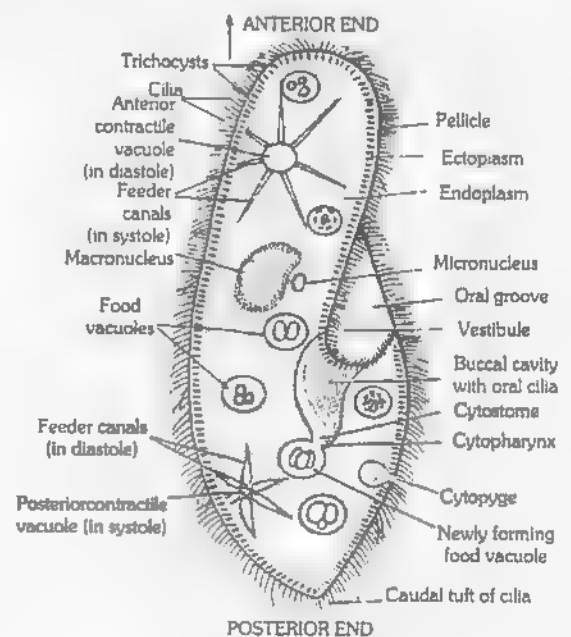
(9) *Paramecium* reproduces by transverse binary fission and nuclear reorganisation. Binary fission occurs during favourable condition. In this process, macronucleus divides amitotically and micronucleus mitotically.

(10) *Paramecium* undergoes several kinds of nuclear reorganisation such as conjugation, autogamy, cytogamy, endomixis and hemimixis. Nuclear reorganisation takes place for rejuvenation.

(11) Conjugation occurs between two mating types of same species of *Paramecium*. It is a modified form of cross fertilization. Each conjugant produces a female stationary and a male migratory nucleus by three successive divisions of micronucleus. They are called pronuclei.

(12) Synkaryon is the diploid nucleus formed by the fusion of stationary and migratory nuclei in conjugant. Synkaryon divides thrice to form eight nuclei. At the end of the conjugation each *Paramecium* (exconjugant) produces four daughter *Paramecia*.

(13) Autogamy is a process of self fertilization. It occurs in a single animal of *P. aurelia*. Autogamy results in the production of two daughter *paramecia* from each.


 Fig : 1.3-12 *Paramecium caudatum*

(14) Cytogamy occurs in *P. caudatum*. The two cytogametes do not exchange their male pronuclei. Endomixis occurs in *P. aurelia*. It is an asexual reproduction and one individual produces four daughter paramecia. Hemimixis is the process of purification act on the part of meganucleus.

(15) Paramecium has kappa, Lambda, Mu and Pi particles in cytoplasm. They differentiate paramecia between sensitive and killer forms.

## Tips & Tricks

✚ Dinoflagellates with bioluminescence/phosphorescence due to light producing protein luciferin are called **fire algae**. e.g., *Noctiluca*, *Pyrocystis*, *Pyrodinium* etc. *Noctiluca* is also called 'night light'.

✚ Dinoflagellates symbionts in other protists and invertebrates are called zooxanthellae.

✚ Some dinoflagellates produce red tides of oceans. e.g., *Gonyaulax*, *Gymnodinium* etc.

✚ Photosynthetic protists fix about 80% of  $CO_2$  in the biosphere.

✚ The siliceous frustules of diatoms do not decay easily. They pile up at the bottom of water reservoirs and form big heaps called diatomite or diatomaceous earth. Diatomite is porous and chemically inert.

✚ 29<sup>th</sup> August is celebrated as the 'mosquito day' because Sir Ronald Ross established mosquito malaria relationship on August 29, 1897. He got Nobel prize in 1902.

✚ 20<sup>th</sup> August is malaria day. Ministry of health, government of India started National Malaria Eradication Programme (NMEP) in the year 1953.

✚ Some protozoans have a loose exoskeleton called "Lorica house" on them.

✚ The fastest reproducing protozoan is 'Glaucoma'. It produces 6-generation within 24 hrs.

✚ Oblique binary fission in *Ceratium*.

✚ *Polystomella* is dimorphic rhizopod which shows metagenesis or alternation of generation in its life cycle.

✚ *Leishmania* is an intracellular parasite of man and other mammals. It causes Leishmaniasis. *L. donovani* causes Kala-azar in man.

✚ *Proterospongia* is a fresh water colonial and free living flagellate and is connecting link between protozoa and porifera

✚ Certain protozoan like *Colonympha* and *Trichonympha* help in digestion of cellulose in certain insects.

✚ Flagellates are more simplest protozoan while ciliates are most complex protozoans.

✚ *E. coli* found as an endocommensal in the colon of about 50% population. It is non-pathogenic.



## Ordinary Thinking

### Objective Questions

#### Photosynthetic and consumer protists

- Nutrition in protists is [AFMC 2008]
  - Holophytic
  - Holozoic
  - Saprophytic
  - All of these
- Which of the following is a slime mould [CBSE PMT 2007]
  - Rhizopus*
  - Physarum*
  - Thiobacillus*
  - Anabaena*
- The thalloid body of a slime mould (Myxomycetes) is known as [CBSE PMT 2006]
  - Fruiting body
  - Mycelium
  - Protonema
  - Plasmodium
- Which of the following are the characters of dinoflagellates
  - Planktonic golden yellow algae with soap box like structure
  - Marine red biflagellated protista
  - Appear yellow, green, brown, blue and red in colour
  - Biflagellated organisms with pellicle
  - Saprophytic (or) parasitic unicellular forms
 [Kerala PMT 2012]
  - A, B and C only
  - B, D and E only
  - B and C only
  - B and E only
  - C, D and E only
- Planktons are organisms which
  - Float on water surface
  - Are free swimmers
  - Are deep sea forms
  - Are burrowing forms
- If phytoplanktons are destroyed in the sea, then
  - No effect will be seen
  - Primary consumers will grow luxuriantly
  - It will affect the food chain
  - Algae will get more space to grow
- Which one of the following is a saprophytic protist [NCERT; Kerala PMT 2012]
  - Desmid
  - Slime mould
  - Euglena*
  - Gonyaulax*
  - Nostoc*
- Slime moulds in the division Myxomycota (true slime moulds) have [AFMC 2006]
  - Pseudoplasmodia
  - Spores that develop into free living amoeboid cells
  - Spores that develop into flagellated gametes
  - Feeding stages consisting of solitary individual cells
- Auxospores and hormocysts are formed respectively by [CBSE PMT 2005; AIIMS 2007]
  - Some cyanobacteria and many diatoms
  - Several cyanobacteria and several diatoms
  - Some diatoms and several cyanobacteria
  - Several diatoms and a few cyanobacteria

10. Flagellum of *Astasia/Euglena* is [APMEE 2002]
  - (a) Pantonematic (b) Acronematic
  - (c) Pantachronematic (d) Stichonematic
11. The slime moulds are characterized by the presence of [MH CET 2003; BHU 2004]
  - (a) Elaters (b) Pseudoelaters
  - (c) Capillitium (d) Capitulum
12. Diatoms are [BHU 2000]
  - (a) Fungi (b) Plantae
  - (c) Protista (d) Protozoans
13. Red oceanic tides can be due to
  - (a) Diatoms (b) Dinophyceae
  - (c) Red algae (d) Blue-green algae
14. Murein is not found in the cell wall of [KCET 2004]
  - (a) *Nostoc* (b) Eubacteria
  - (c) Cyanobacteria (d) Diatoms
15. Slime moulds belong to
  - (a) Fungi (b) Protista
  - (c) Monera (d) Plantae
16. Spore producing body of a cellular slime mould is
  - (a) Pseudoplasmodium (b) Plasmodium
  - (c) Sporangium (d) Sporophore
17. Transverse groove present in dinoflagellates is
  - (a) Sulcus (b) Cingulum
  - (c) Annulus (d) Both (b) and (c)
18. Protistan genome has [CBSE PMT 1994]
  - (a) Membrane bound nucleoproteins embedded in cytoplasm
  - (b) Free nucleic acid aggregates
  - (c) Gene containing nucleoproteins condensed together in loose mass
  - (d) Nucleoprotein in direct contact with cell substance
19. Which protist reproduces both by binary fission and conjugation
  - (a) *Amoeba* (b) *Paramecium*
  - (c) *Euglena* (d) *Monocystis*
20. Protists obtain food as [CBSE PMT 1994]
  - (a) Photosynthesisers, symbionts and holotrophs
  - (b) Photosynthesisers
  - (c) Chemosynthesisers
  - (d) Holotrophs
21. Which one is not a protozoan protist [Manipal 1995]
  - (a) *Plasmodium vivax*
  - (b) *Paramecium caudatum*
  - (c) *Enterobius vermicularis*
  - (d) *Trypanosoma gambiense*
22. Which of the following animal is having longitudinal binary fission [Kerala PMT 2007]
  - (a) *Euglena* (b) *Plasmodium*
  - (c) *Planaria* (d) *Paramecium*
  - (e) *Hydra*
23. *Euglena* is a [CPMT 1998]
  - (a) Ciliate (b) Sporozoan
  - (c) Flagellate (d) Sarcodine
24. Protozoans are able to live efficiently due to their [AMU (Med.) 1999]
  - (a) Motility
  - (b) Rapid reproduction
  - (c) Ability to manufacture food
  - (d) Specialised organelles
25. Characteristic spores of diatoms are [KCET 1999; Kerala PMT 1999]
  - (a) Ascospores (b) Basidiospores
  - (c) Auxospores (d) Zoospores
26. Unlike other algae, diatoms do not readily decay due to [NCERT; BHU 1999]
  - (a) Siliceous wall
  - (b) Mucilaginous wall
  - (c) Water proof cell wall
  - (d) Nonliving cells
27. Which one of the following can photosynthesise its food [JIPMER 1997; KCET 1999; CPMT 2003; VITEEE 2008]
  - (a) *Hydra* (b) *Paramecium*
  - (c) *Monocystis* (d) *Euglena*
28. Sexual reproduction in protists with diploid chromosomes involves [RPMT 1999; Chd. CET 2000]
  - (a) Cyst formation (b) Zygotic meiosis
  - (c) Gametangial meiosis (d) Binary fission
29. Diatom frustule/shell is made of [NCERT; BHU 1998; Manipal 2001]
  - (a) Silica (b) Lime
  - (c) Magnesium carbonate (d) Calcium
30. Which one of the following is a unicellular, nonmotile desmid [KCET 2010]
  - (a) *Chlorobium* (b) *Clostridium*
  - (c) *Chromatium* (d) *Cosmarium*
31. Protista contains [Odisha JEE 2002]
  - (a) *Euglena*, Dinoflagellates and Yeast
  - (b) *Amoeba*, *Paramecium*, *Hydra*
  - (c) *Euglena*, *Paramecium*, Mushroom
  - (d) *Amoeba*, *Paramecium* and Dinoflagellates
32. *Ceratium* is [APMEE 2002]
  - (a) Dinoflagellate (b) Diatom
  - (c) Slime mould (d) Sporozoan

### Protozoan protists

1. The class of phylum protozoa to which '*Noctiluca*' belongs, is
  - (a) Rhizopoda (b) Sporozoa
  - (c) Mastigophora (d) Ciliata



2. In the diagram, which of the following processes are shown in *Amoeba*



[KCET 2007]

- (a) Exocytosis (b) Phagocytosis  
(c) Pinocytosis (d) All of these
3. Slimy mass of protoplasm with many nuclei and an *Amoeba* like thalloid body is a characteristic feature of  
[NCERT; Kerala PMT 2009]  
(a) Ascomycetes (b) Actinomycetes  
(c) Phycomycetes (d) Basidiomycetes  
(e) Myxomycetes
4. The class of *Trichonympha* is [MP PMT 2000]  
(a) Calcaria (b) Scyphozoa  
(c) Sporozoa (d) Mastigophora
5. The infection of *Entamoeba histolytica* takes place by [CPMT 2009]  
(a) Trophozoite (b) Binucleated cyst  
(c) Trinucleated cyst (d) Quadri-nucleated cyst
6. *Paramecium* is a [Odisha JEE 2008]  
(a) Protozoan (b) Bacterium  
(c) Virus (d) Annelid
7. Which is not the locomotory organ of protozoa [AFMC 2003, 05; MP PMT 2003]  
(a) Cilia (b) Flagella  
(c) Pseudopodia (d) Parapodia
8. *Monocystis* belongs to the order [MP PMT 2002]  
(a) Gregarinida (b) Coccidia  
(c) Microsporidia (d) Sarcosporidia
9. Which protozoan is unlikely to have a contractile vacuole [BHU 2001; CBSE PMT 2001]  
(a) *Euglena* (b) *Paramecium*  
(c) *Amoeba* (d) *Plasmodium*
10. *Entamoeba histolytica* is a human parasite usually found in [KCET 1999]  
(a) Liver (b) Lung  
(c) Mouth (d) Intestine
11. The protozoan parasite which possesses a food vacuole is [EAMCET 1998]  
(a) *Leptomonas* (b) *Plasmodium*  
(c) *Trypanosoma* (d) *Leishmania*
12. Which one of the following pairs is correctly matched [RPMT 2005]  
(a) Aedes – plague (b) Anopheles – malaria  
(c) House fly – yellow fever (d) Body louse – typhoid
13. Total parasites belong to protozoan group [CPMT 2001, 09; BHU 2002]  
(a) Sporozoa (b) Ciliata  
(c) Sarcodina (d) Zooflagellata

14. Which of the following classes of protozoa is exclusively endoparasite [CPMT 1998]  
(a) Mastigophora (b) Sarcodina  
(c) Opalinata (d) Sporozoa

15. Match the following and choose the correct combination from the options given

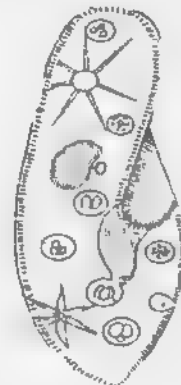
Column I (Group Protista)		Column II (Example)	
A.	Chrysophytes	i.	<i>Paramecium</i>
B.	Dinoflagellates	ii.	<i>Euglena</i>
C.	Euglenoids	iii.	<i>Gonyaulax</i>
D.	Protozoans	iv.	Diatoms

[NCERT; Kerala PMT 2008; AMU (Med.) 2012]

- (a) A – i, B – iii, C – ii, D – iv  
(b) A – ii, B – iv, C – iii, D – i  
(c) A – iv, B – ii, C – iii, D – i  
(d) A – iii, B – iv, C – i, D – ii  
(e) A – iv, B – iii, C – ii, D – i
16. Which is not true for *Paramecium* [Odisha JEE 2009]  
(a) Under unfavourable conditions, form cysts  
(b) Presence of large number of cilia on whole body surface  
(c) Contain contractile vacuoles for osmoregulation  
(d) Use pseudopodia for capturing prey
17. Which of the following combination of characters is true of slime moulds [DUMET 2009]  
(a) Parasitic, *Plasmodium* with true walls, spores dispersed by air currents  
(b) Saprophytic, *Plasmodium* without walls, spores dispersed by water  
(c) Parasitic, *Plasmodium* without walls, spores dispersed by water  
(d) Saprophytic, *Plasmodium* without walls, spores dispersed by air currents
18. Slipper animalcule is [Manipal 2005]  
(a) *Paramecium* (b) *Trypanosoma*  
(c) *Entamoeba* (d) Protozoa
19. In life cycle of *Plasmodium*, exflagellation is seen in [CPMT 2005]  
(a) Microgametocytes (b) Trophozoites  
(c) Macrogametocytes (d) Merozoites
20. Man in the life cycle of *Plasmodium* is [AFMC 2005]  
(a) Primary host (b) Secondary host  
(c) Intermediate host (d) None of these
21. Which of the following unicellular organism has a macronucleus for trophic function and one or more micronuclei for reproduction [AMU (Med.) 2005; CBSE PMT 2005]  
(a) *Euglena* (b) *Amoeba*  
(c) *Paramecium* (d) *Trypanosoma*
22. Pseudopodia is a characteristic feature of which class  
(a) Mastigophora (b) Sarcodina  
(c) Sporozoa (d) Ciliata
23. Animals of class ciliata  
(a) Have two nuclei (b) Are autotrophs  
(c) Reproduce sexually (d) Possess cilia

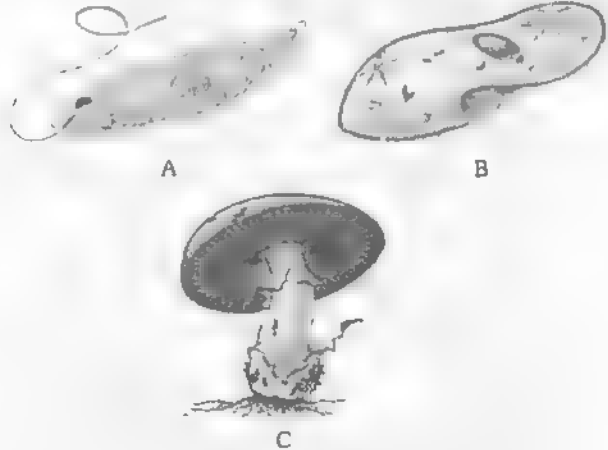
24. Excretion in *Amoeba* occurs through [CPMT 1999]  
(a) Nucleus (b) Parapodia  
(c) Plasmalemma (d) Contractile vacuole
25. The reason of pseudopodium formation is [RPMT 1999]  
(a) Chemical changes  
(b) Difference in the viscosity  
(c) Difference in the pressure  
(d) Change in the temperature
26. Who discovered malaria parasite [CPMT 1996; RPMT 1999]  
(a) Sir Ronald Ross (b) Charles Laveran  
(c) Patrick Manson (d) Grassi
27. Sporogony of malarial parasite occurs in [APMEE 1996; BHU 1996, 2002; AIIMS 1999; DPMT 2004]  
(a) Liver of man  
(b) RBCs of man  
(c) Stomach wall of mosquito  
(d) Salivary glands of mosquito
28. Which of the following is not true for nutrition in *Amoeba* [Odisha JEE 2005]  
(a) Photoheterotrophic (b) Phagocytosis  
(c) Intracellular (d) Holozoic
29. Which is filter feeder [MP PMT 1995]  
(a) *Amoeba* (b) *Leech*  
(c) *Spider* (d) *Paramecium*
30. Sexual mode of reproduction in protozoa is [Odisha JEE 2005]  
(a) Anisogamy (b) Plasmotomy  
(c) Autogamy (d) Schizogony
31. *Paramoecium* exhibits cytoplasmic inheritance through [BHU 2012]  
(a) Chromosome (b) Nuclear gene  
(c) Kappa particles (d) DNA
32. Class sporozoa of phylum protozoa is characterised by [CMC Vellore 1993]  
(a) Flagella (b) Cilia  
(c) Parasitism (d) None of these
33. Primary grouping of protozoan protists is based on [MP PMT 1996, 99, 2002, 10; CPMT 1998; AIIMS 1999; Pb. PMT 2002; DPMT 2002; AFMC 2009]  
(a) Locomotor organelles (b) Size and shape  
(c) Mode of feeding (d) Mode of reproduction
34. *Amoeba* was described in detail by [RPMT 1999]  
(a) Ronald Ross (b) Aristotle  
(c) Hirshfield (d) Rossenhoff
35. Conjugation in protozoa is found in [RPMT 2001]  
(a) Sarcodina (b) Flagellata  
(c) Sporozoa (d) Ciliata
36. Which one of the following represents class Mastigophora [MP PMT 2001]  
(a) *Monocystis* (b) *Paramecium*  
(c) *Trypanosoma* (d) *Amoeba*
37. Maurer's dots occurs in human RBCs infected by [MP PMT 2002]  
(a) *Plasmodium falciparum* (b) *Plasmodium ovale*  
(c) *Plasmodium vivax* (d) *Plasmodium malariae*
38. Which one show bioluminescence [BHU 2003]  
(a) *Noctiluca* (b) *Polystomella*  
(c) *Entamoeba* (d) *Suctorla*
39. Protists are  
1. Unicellular and prokaryote  
2. Unicellular and eukaryote  
3. Multicellular and eukaryote  
4. Autotroph and heterotroph [BHU 2003]  
(a) 1 + 2 + 3 (b) 2 + 3 + 4  
(c) 3 + 4 (d) 2 + 4
40. Locomotory organ of sporozoa is [Bihar MDAT 1995]  
(a) Tentacles (b) Reticulocytes  
(c) Legs (d) None of the above
41. *Paramecium* ingests food through [CMC 2002]  
(a) Cytoproct (b) Cytopyge  
(c) Cytopharynx (d) Cytostome
42. When a fresh-water protozoan possessing a contractile vacuole, is placed in a glass containing marine water, the vacuole will [CPMT 1993; DPMT 2001; CBSE PMT 2004; KCET 2010, 11]  
(a) Increase in size (b) Decrease in size  
(c) Increase in number (d) Disappear
43. Which is false for nutrition in *Amoeba* [Odisha JEE 2004]  
(a) Omnivorous (b) Pseudopodia feeder  
(c) Holozoic nutrition (d) Photoautotroph
44. Which is not related with the sexual reproduction in protozoans [Odisha JEE 2004]  
(a) Cytogamy (b) Autogamy  
(c) Conjugation (d) Schizogony
45. All protozoans have [Odisha JEE 2004]  
(a) Pseudopodia (b) Eukaryotic organisation  
(c) Contractile vacuole (d) Holozoic nutrition
46. .... is not true for *Euglena* [Odisha JEE 2004]  
(a) Presence of chl. - 'a' and 'b'  
(b) Presence of protoplasmic capsule  
(c) Presence of cellulose cell wall  
(d) Presence of proteinaceous pellicle
47. A metazoa without tissue organisation is called [Pb. PMT 2004]  
(a) Parazoa (b) Protozoa  
(c) Eumetazoa (d) Dermatozoa
48. Passive food ingestion in *Amoeba* is known as [DPMT 2004; BHU 2004]  
(a) Import (b) Invagination  
(c) Circumfluence (d) Circumvallation
49. Reproduction in *Paramecium* is controlled by [BVP 2001]  
(a) Flagella (b) Micronucleus  
(c) Macronucleus (d) Cell wall
50. *Trichonympha* is a symbiont in alimentary canal of [APMEE 2002]  
(a) Earthworm (b) Snails  
(c) Hermit Crab (d) Termite

51. In which of the following binary fission is not seen [Odisha JEE 2005]  
(a) Plasmodium (b) Amoeba  
(c) Euglena (d) Paramecium
52. Amoeba is a member of Phylum [MP PMT 2012]  
(a) Porifera (b) Protozoa  
(c) Annelida (d) Mollusca
53. Which of the following is a flagellated protozoan [Kerala PMT 2010, 12]  
(a) Amoeba (b) Entamoeba  
(c) Plasmodium (d) Trypanosoma  
(e) Paramecium
54. Mammalian kidney resemble contractile vacuole of Amoeba in excretion of [MP PMT 2006]  
(a) Glucose (b) Excess water  
(c) Urea (d) Ammonia
55. In Paramecium, both autogamy and conjugation are sexual processes because of  
(a) Gene recombination  
(b) Involvement of two individuals  
(c) Fusion of two haploid nuclei  
(d) Rejuvenation
56. All stages of Plasmodium are digested in stomach of female Anopheles except [CPMT 2002; RPMT 2005]  
(a) Sporozoites (b) Gametocytes  
(c) Erythrocytes (d) Merozoites
57. Which one of the following genus of insects prefer to breed in clean water and their larvae lie parallel to the surface of water [WB JEE 2012]  
(a) Anopheles (b) Culex  
(c) Aedes (d) Phlebotomus
58. The stage of Entamoeba histolytica that causes intestinal ulceration is [RPMT 2000]  
(a) Trophozoite (b) Metacystic trophozoite  
(c) Binucleate stage (d) Tetranucleate stage
59. If a pond dries, Amoeba  
(a) Reproduces (b) Encysts  
(c) Degenerates (d) Behaviour is uncertain
60. Which of the following is not correct with respect to malaria [KCET 2015]  
(a) RBC's rupture and release haemozoin which causes chills  
(b) Sporozoites multiply in blood  
(c) Female anopheles mosquito is the vector  
(d) Malignant malaria is caused by Plasmodium falciparum
61. The active form of Entamoeba-histolytica feeds upon [AIPMT (Cancelled) 2015]  
(a) Mucosa and submucosa of colon only  
(b) Food in intestine  
(c) Blood only  
(d) Erythrocytes; mucosa and submucosa of colon
62. Microphagial nutrition occurs in [Kerala PMT 2006]  
(a) Amphioxus (b) Insects  
(c) Paramecium (d) Hydra  
(e) Euglena
63. Which structure is formed at the time of exchange of gamete nuclei in given animal during sexual reproduction [GUJCET 2015]



- (a) Plasmodesmata (b) Cytoplasmic filaments  
(c) Internal tubule (d) Cytoplasmic bridge
64. Entamoeba differs from Amoeba is not having [RPMT 1995; AMU (Med.) 2002; MP PMT 2004; BHU 2005]  
(a) Nucleus (b) Pseudopodia  
(c) Ectoplasm (d) Contractile vacuole
65. The cilia in Paramecium are  
(a) All equal (b) All unequal  
(c) Longer at posterior end (d) Longer at anterior end
66. Sprinkling oil over ponds would control malaria because [AFMC 2001]  
(a) Fishes die (b) Water gets polluted  
(c) Larvae are asphyxiated (d) Mosquitoes are repelled
67. Which of the following is not a character of protista [Kerala PMT 2010]  
(a) Protists are prokaryotic  
(b) Some protists have cell walls  
(c) Mode of nutrition is both autotrophic and heterotrophic  
(d) Body organization is cellular  
(e) Membrane bound organelles are present in cells
68. Transverse binary fission occurs in [DPMT 2007]  
(a) Euglena (b) Amoeba  
(c) Hydra (d) Paramecium
69. Living Amoeba is  
(a) Pale blue (b) Transparent  
(c) Light green (d) Translucent
70. Discovery of Amoeba was made by  
(a) Jenner (b) Rossenhoff  
(c) Hofkins (d) Twait
71. Chrysophytes, Euglenoids, Dinoflagellates and Slime moulds are included in the kingdom [NEET (Phase-I) 2016]  
(a) Monera (b) Protista  
(c) Fungi (d) Animalia
72. Paramecium moves about by  
(a) Pseudopodia (b) Cilia  
(c) Flagella (d) Looping and crawling
73. In which group of organisms the cell walls form two thin overlapping shells which fit together [AIPMT 2015]  
(a) Euglenoids (b) Dinoflagellates  
(c) Slime moulds (d) Chrysophytes

74. Locomotory structures of *Amoeba* are [BHU 2001]  
(a) Cilia (b) Flagella  
(c) Pseudopodia (d) None of the above
75. Mode of nutrition in *Trypanosoma* is [DPMT 2006]  
(a) Saprophytic (b) Parasitic  
(c) Autotrophic (d) Phototrophic
76. Quartan malaria is due to [NCERT; RPMT 1995; Bihar CECE 1995; Odisha JEE 1995, 2005; BHU 1996; MP PMT 2001]  
Or  
Your patient shows paroxysms of malaria after every 72 hours. Which species of plasmodium will be considered responsible to cause the infection [NCERT]  
(a) *Plasmodium falciparum* (b) *P. vivax*  
(c) *P. ovale* (d) *P. malariae*
77. Malignant tertian malaria is due to [NCERT]  
Or  
Cerebral malaria is due to [CBSE PMT 1991; APNEE 1995, 2002; Bihar MDAT 1996, 2002; RPMT 2000, 06; AIIMS 2000; MP PMT 2004; BHU 2008; Odisha JEE 2009]  
(a) *Plasmodium falciparum* (b) *P. vivax*  
(c) *P. ovale* (d) *P. malariae*
78. Male mosquito (*Anopheles*) does not transmit malarial parasite because  
(a) It lacks blood sucking mouth parts  
(b) It catches fever  
(c) It is too small to carry parasite  
(d) The parasite is killed in its stomach
79. Highest incubation period occurs in *Plasmodium* [CPMT 2001]  
(a) *P. malariae* (b) *P. vivax*  
(c) *P. ovale* (d) *P. falciparum*
80. *Entamoeba histolytica* infection occurs through  
(a) Contaminated water and food  
(b) Sweat  
(c) Bird droppings  
(d) Mosquito bites
81. Malarial parasite is [Bihar PMT 2000]  
(a) Polygenetic (b) Digenetic  
(c) Monogenetic (d) Monomorphic
82. Type of pseudopodia present in *Amoeba proteus* is  
(a) Lobopodia (b) Axopodia  
(c) Filopodia (d) Exopodia
83. Erythrocytic phase of *Plasmodium vivax* is completed in [Bihar PMT 2000]  
(a) 24 hours (b) 72 hours  
(c) 36 hours (d) 48 hours
84. Schuffner's dots observed in erythrocytes are due to  
(a) Filaria (b) Malaria  
(c) Kala-azar (d) Giardia
85. The part of life cycle of malarial parasite *Plasmodium vivax*, that is passed in female *Anopheles* is [CBSE PMT 1992]  
(a) Sexual cycle  
(b) Pre-erythrocytic schizogony  
(c) Exoerythrocytic schizogony  
(d) Post-erythrocytic schizogony
86. Erythrocytic cycle of *Plasmodium* occurs in  
(a) Liver (b) Spleen  
(c) RBC (d) Gut
87. Which one is correct pairing [Manipal 2001]  
(a) *Hydra*-Anthozoa (b) *Paramecium*-Arachnida  
(c) *Plasmodium*-Sporozoa (d) *Amoeba*-Ciliata
88. Presence of two types of nuclei, micronucleus and macronucleus, is characteristic of protistan group  
(a) Sporozoa (b) Ciliata  
(c) Flagellata (d) Sarcodina
89. Which one resides in the mouth of human beings [MP PMT 1995]  
(a) *Entamoeba coli* (b) *Entamoeba histolytica*  
(c) *Entamoeba gingivalis* (d) *Amoeba proteus*
90. Which one does not spread disease [RPMT 1995; Pb. PMT 2000]  
(a) *Entamoeba coli* (b) *Entamoeba histolytica*  
(c) *E. gingivalis* (d) *Plasmodium ovale*
91. Which one is monogenetic parasite [RPMT 1995]  
(a) *Plasmodium* (b) Liver Fluke  
(c) *Taenia solium* (d) *Entamoeba histolytica*
92. *Amoeba* touched with needle will [RPMT 1995]  
(a) Die (b) Divide quickly  
(c) Develop pseudopodia (d) Move away
93. Infective stage of *Trypanosoma gambiense* is [APMEE 1995; AIIMS 1999; DPMT 1999]  
(a) Metacyclic (b) Crithidial  
(c) Leptomonas (d) Leishmania
94. Which does not occur in sporozoa [Bihar MDAT 1995]  
(a) Cilia (b) Pseudopodia  
(c) Flagella (d) None of the above
95. In malaria, which causes chills and fever [NCERT; BHU 1995; MPPMT 1997]  
Or  
Metabolic waste responsible for malaria fever is called  
Or  
The poisonous substance released as a result of rupturing of schizont in RBC of malaria patient is [RPMT 2005]  
(a) Hematin (b) Haemozoin  
(c) Schuffner's granules (d) Hematocrit
96. Development and functioning of gametocytes of *Plasmodium* in the body of Mosquito are dependent upon [RPMT 1996]  
(a) Temperature (b) Food  
(c) Position (d) All the above
97. Who was awarded Nobel Prize in 1902 for discovery of oocyst of *Plasmodium* [RPMT 1996]  
Or  
Who discovered oocysts in the stomach of female *Anopheles* [MP PMT 2009]  
Or  
Malaria is transmitted by "*Anopheles*". This was discovered by  
(a) Golgi (b) Ronald Ross  
(c) Laveran (d) Short
98. Which one is spindle-shaped mobile with microtubules [RPMT 1996]  
(a) Sporont (b) Ookinete  
(c) Cryptozoite (d) Sporozoite

99. Infection of *Entamoeba histolytica* is prevented by [CPMT 1996]  
 (a) Avoiding kissing  
 (b) Avoiding clothes of patient  
 (c) Uncontaminated food  
 (d) None of the above
100. Trichocyst takes part in [CPMT 1996]  
 (a) Defence (b) Reproduction  
 (c) Nutrition (d) Osmoregulation
101. Cyst wall of *Euglena* is formed of [APMEE 2000, 02]  
 (a) Silica (b) Carbohydrate  
 (c) Proteins (d) Calcium
102. Posterior end of *Amoeba* is characterised by [Bihar MDAT 1996]  
 (a) Plasmid (b) Amphid  
 (c) Uropigium (d) Lack of food vacuoles
103. Multiple fission in *Plasmodium* is [DPMT 1996]  
 (a) Gamogamy (b) Schizogony  
 (c) Sporulation (d) None of the above
104. Development of gametocyte from merozoite of *Plasmodium* occurs in [DPMT 1996]  
 (a) Red blood corpuscles  
 (b) Liver cells  
 (c) Stomach of female *Anopheles*  
 (d) All the above
105. A cyst of *Entamoeba histolytica* produces trophozoites [DPMT 1996]  
 (a) 1 (b) 2  
 (c) 4 (d) 18
106. Which one is not a symptom of *Entamoeba histolytica* infection [BHU 1996]  
 (a) Relapsing fever (b) Abdominal pain  
 (c) Blood in stool (d) Irregular bowels
107. Malarial species found in South America and West Africa is [BHU 1996]  
 (a) *Plasmodium falciparum* (b) *P. vivax*  
 (c) *P. malariae* (d) *P. ovale*
108. Recurrence of high temperature in malaria at intervals is due to completion of [BHU 1996; AIIMS 1996; CPMT 1997]  
 (a) Erythrocytic schizogony  
 (b) Sporogony  
 (c) Gamogony  
 (d) Exoerythrocytic schizogony
109. Symptoms of malaria in spleen and skin are due to [BHU 1996]  
 (a) Schuffner's granules (b) Haemozoin  
 (c) Hamaton (d) Blood sugar
110. *Entamoeba histolytica* excretes through [MP PMT 1996]  
 (a) Food vacuole (b) General surface  
 (c) Contractile vacuole (d) Malpighian tubules
111. What is common about *Trypanosoma*, *Noctiluca*, *Monocystis* and *Giardia* [CBSE PMT 2006]  
 (a) They produce spores  
 (b) These are all parasites  
 (c) These are all unicellular protists  
 (d) They have flagella
112. Which one of the following is a characteristic feature of Chrysophytes [Kerala PMT 2011]  
 (a) They are parasitic forms which cause diseases in animals  
 (b) They have a protein rich layer called pellicle  
 (c) They have indestructible wall layer deposited with silica  
 (d) They are commonly called dinoflagellates  
 (e) They are saprophytic protists
113. Infective stage of *Entamoeba histolytica* is [CPMT 1997; Manipal 1999; Pb. PMT 1999; BHU 2002]  
 (a) Trophozoite (b) Pre-cyst  
 (c) Uninucleate cyst (d) Tetranucleate cyst
114. Sandfly is causative agent of [CPMT 1997; AMU (Med.) 2001; MP PMT 2002]  
 (a) Kala-azar (b) Sleeping sickness  
 (c) Typhoid (d) Dysentery
115. *Leishmania tropica* produces [AMU (Med.) 1998; MP PMT 2011]  
 (a) Sleeping sickness (b) Kala-azar  
 (c) Dysentery (d) Oriental sores
116. *Trypanosoma brucei* produces [BHU 1998]  
 (a) Sleeping sickness (b) Kala-azar  
 (c) Dysentery (d) A disease of animals
117. Which of the following does not belong to the kingdom Protista [Kerala PMT 2011]  
 (a) Chrysophytes (b) Euglenoids  
 (c) Ascomycetes (d) Dinoflagellates  
 (e) Protozoans
118. Protozoan found commensal in human colon is [CPMT 1998; DPMT 2006]  
 (a) *Entamoeba coli* (b) *P. vivax*  
 (c) *A. aegypti* (d) All the above
119. Symptoms of paroxysms in malaria are due to [RPMT 1998]  
 (a) Sporozoite (b) Gametocyte  
 (c) Pre-erythrocytic cycle (d) Erythrocytic cycle
120. Relapsing malaria is due to [RPMT 1998]  
 (a) *Plasmodium falciparum* and *P. vivax*  
 (b) *Plasmodium ovale* and *P. vivax*  
 (c) *Plasmodium falciparum* and *P. ovale*  
 (d) *P. falciparum* only
121. Study the following figures and identify A, B and C [NCERT]
- 

A                      B  
C
- (a) A – *Euglena*, B – *Paramecium*, C – *Aspergillus*  
 (b) A – *Planaria*, B – *Paramecium*, C – *Agaricus*  
 (c) A – *Euglena*, B – *Planaria*, C – *Agaricus*  
 (d) A – *Euglena*, B – *Paramecium*, C – *Agaricus*
122. Signet ring stage of *Plasmodium* represents [MP PMT 1999; CPMT 2010]  
 (a) Beginning of schizogony in liver cells  
 (b) End of schizogony in RBC  
 (c) Beginning of schizogony in RBC  
 (d) Beginning of sporogony in humans

123. *Amoeba* is eukaryotic because it possesses [APMEE 1999]  
 (a) Plasmid (b) Nucleus  
 (c) Plasmalemma (d) DNA
124. Incubation period of *Plasmodium vivax* is [DPMT 1999; WB JEE 2009; MP PMT 2012]  
 (a) 14 days (b) 20 days  
 (c) 30 days (d) 45 days
125. In *Amoeba*, contractile vacuole is present [CPMT 2000; BHU 2006]  
 (a) Near trailing end (b) Near advancing end  
 (c) At the middle of body (d) Any where inside body
126. Select the wrong statement [NEET (Phase-II) 2016]  
 (a) Diatoms are microscopic and float passively in water  
 (b) The walls of diatoms are easily destructible  
 (c) 'Diatomaceous earth' is formed by the cell walls of diatoms  
 (d) Diatoms are chief producers in the oceans
8. Periodic appearance of malaria symptoms occurs due to periodic  
 (a) Entry of merozoites into erythrocytes  
 (b) Attack of liver cells by merozoites  
 (c) Formation of signet ring  
 (d) Release of pyrogen in blood
9. Motile elongate zygote of *Plasmodium* occurs in [NCERT; CPMT 1999; CBSE PMT (Pre.) 2012]  
 (a) Human RBCs  
 (b) Human liver  
 (c) Salivary glands of mosquito (*Anopheles*)  
 (d) Gut of mosquito (*Anopheles*)
10. In *Amoeba*, pseudopodia are formed due to [RPMT 1995]  
 (a) Contact with food  
 (b) Sol  $\rightleftharpoons$  gel change  
 (c) Movement towards area of higher temperature  
 (d) All the above
11. Which stage of *Plasmodium* is infective for Mosquito [RPMT 1996]  
 (a) Trophozoite (b) Gametocyte  
 (c) Ookinete (d) Sporozoite
12. Chromatid bodies occurs in *Entamoeba* during [APMEE 1996; Pb. PMT 1999; AIIMS 2002]  
 (a) Precyst stage (b) Early cysts  
 (c) Tetranucleate cysts (d) Trophozoites
13. *Amoeba* stops producing pseudopodia during [HPMT 2001]  
 (a) Alkaline condition (b) Starvation  
 (c) Acidic condition (d) Touch
14. After how many days could a patient commonly feel malaria from the time of biting of mosquito [CPMT 1998]  
 (a) 2 – 8 days (b) 8 – 10 days  
 (c) 10 – 20 days (d) 20 – 30 days
15. Microfossils often present in petroleum producing formation are those of [AMU (Med.) 2001]  
 (a) Radiolarians (b) Diatoms  
 (c) Heliozoans (d) Foraminiferans
16. *Amoeba* moves when [RPMT 2002]  
 (a) Upper part of plasma-gel changes to plasmasol  
 (b) Lower part of plasmasol changes into gel  
 (c) Upper part of plasmasol changes into plasmagel  
 (d) All the above
17. A person suffering from a disease caused by *Plasmodium*, experiences recurring chill and fever at the time when [NCERT; CPMT 1998; AFMC 2001; CBSE PMT (Mains) 2010]  
 (a) The sporozoites released from RBCs are being rapidly killed and broken down inside spleen  
 (b) The trophozoites reach maximum growth and give out certain toxins  
 (c) The parasite after its rapid multiplication inside RBCs ruptures them, releasing the stage to enter fresh RBCs  
 (d) The microgametocytes and megagametocytes are being destroyed by the WBCs
18. Destruction of nucleus in *Amoeba* results in [RPMT 1995]  
 (a) Immediate death  
 (b) Slowing down of metabolic activity and ultimate death  
 (c) Quick locomotion  
 (d) No change

## GT Critical Thinking

### Objective Questions-

1. The major function of contractile vacuole is [CBSE PMT 1995; CPMT 1996; RPMT 2000; BHU 2006]  
 (a) Excretion (b) Circulation  
 (c) Osmoregulation (d) All the above
2. Centric discoid form of diatom is [HPMT 2001]  
 (a) *Diploneis* (b) *Coscinodiscus*  
 (c) *Stephanodiscus* (d) *Camphyloneis*
3. Which of the following can be used as bacteriological filter [JIPMER 2002]  
 (a) *Gelidium* (b) *Batrachospermum*  
 (c) *Oscillatoria* (d) *Cymbella*
4. Two species of *Amoeba* X and Y were kept in fresh water and got adapted. Species X developed contractile vacuole. When both were transferred to sea water and got adapted, both X and Y lost their contractile vacuole. From these observation we conclude that  
 (a) Both X and Y are marine species  
 (b) Species Y is marine and X is fresh water  
 (c) Species X is marine and Y is fresh water  
 (d) Both X and Y are fresh water
5. *Amoeba* reacts  
 (a) Negatively to strong light and positively to weak light  
 (b) Positively to strong light and negatively to weak light  
 (c) Unaffected by light intensity  
 (d) Positive to both strong and weak light
6. Which is wrong combination [AIIMS 2001]  
 (a) Haemocyanin – Prawn  
 (b) Haemoglobin in mammals – RBC  
 (c) Haemoglobin in plasma – *Pheretima*  
 (d) Haemozoin – *Plasmodium* cytoplasm
7. *Plasmodium*, the malarial parasite, belongs to class [NCERT; CBSE PMT 1990]  
 (a) Sarcodina (b) Ciliata  
 (c) Sporozoa (d) Dinophyceae

19. Exoerythrocytic schizogony of *Plasmodium* takes place in  
[MP PMT 2007]

- (a) RBC  
(b) Leucocytes  
(c) Liver in which cryptomerozoites are formed  
(d) Liver in which metacryptomerozoites are formed

20. In *Plasmodium*, gametocytes are formed from  
[Bihar PMT 1994]

- (a) Schizont (b) Trophozoite  
(c) Sporozoite (d) Merozoite

21. If all ponds and puddles are destroyed, the organism likely to be destroyed is  
[CBSE PMT 1993]

- (a) *Leishmania* (b) *Trypanosoma*  
(c) *Ascaris* (d) *Plasmodium*

22. The chill and fever recurring after 48 hours in benign tertian malaria is due to

- (a) *Plasmodium vivax* (b) *P. malariae*  
(c) *P. falciparum* (d) None of the above

23. In malaria, shivering occurs when  
[AFMC 2001; RPMT 2002; CPMT 2004; WB JEE 2012]

- (a) Schizonts enter R.B.C  
(b) Sporozoites enter human body  
(c) Merozoites are liberated from R.B.C. along with toxin  
(d) Signet ring stage is attained

24. Which one of the following sets of items in the options a-d are correctly categorized with one exception in it  
[NCERT; CBSE PMT (Mains) 2012]

	Items	Category	Exception
(a)	UAA, UAG, UGA	Stop codons	UAG
(b)	Kangaroo, Koala, Wombat	Australian marsupials	Wombat
(c)	<i>Plasmodium</i> , <i>Cuscuta</i> , <i>Trypanosoma</i>	Protozoan parasites	<i>Cuscuta</i>
(d)	Typhoid, Pneumonia, Diphtheria	Bacterial diseases	Diphtheria

25. Which of the following diseases is caused by a protozoan  
[AIPT 2015]

- (a) Influenza (b) Babesiosis  
(c) Blastomycosis (d) Syphilis

26. All eukaryotic unicellular organisms belong to  
[NCERT]

- (a) Monera (b) Protista  
(c) Fungi (d) Bacteria

## Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

- (a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion  
(b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion  
(c) If the assertion is true but the reason is false  
(d) If both the assertion and reason are false  
(e) If the assertion is false but reason is true

1. Assertion : Slime moulds show alternation of generation.

Reason : The sporangia bearing slime moulds represent haplophase.

2. Assertion : Sandfly transmits Kala-azar.

Reason : In Kala-azar, the parasite damages the brain

3. Assertion : *Trichomonas vaginalis* causes infection only in women.

Reason : *Trichomonas buccalis* lives in the buccal cavity

4. Assertion : *Euglena* is studied as an animal as well as a plant.

Reason : *Euglena* is more an animal than a plant.

5. Assertion : *Amoeba* contains a contractile vacuole.

Reason : It helps in both digestion and osmoregulation.

6. Assertion : Amoebiasis is caused by *Amoeba*.

Reason : The protist feeds on red blood corpuscles.

7. Assertion : Erythrocytic merozoites form gametocytes.

Reason : Gametocytes are of two types – male and female.

8. Assertion : *Plasmodium* causes disease in female *Anopheles* mosquitoes.

Reason : Female *Anopheles* mosquitoes feed on human blood.

9. Assertion : Malarial fever appear at merozoite stage of *Plasmodium*.

Reason : The infective stage of *Plasmodium* is sporozoite.

10. Assertion : Schizogony is an asexual reproduction of female *Anopheles* mosquito.

Reason : It takes place only in human liver cells.

## Answers

### Photosynthetic and consumer protists

1	d	2	b	3	d	4	c	5	a
6	c	7	b	8	c	9	d	10	d
11	c	12	c	13	b	14	d	15	b
16	c	17	d	18	a	19	b	20	a
21	c	22	a	23	c	24	d	25	c
26	a	27	d	28	c	29	a	30	d
31	d	32	a						

### Protozoan protists

1	c	2	b	3	e	4	d	5	d
6	a	7	d	8	a	9	d	10	d
11	b	12	b	13	a	14	d	15	e
16	d	17	d	18	a	19	a	20	a



21	c	22	b	23	a	24	c	25	b
26	b	27	c	28	a	29	d	30	a
31	c	32	c	33	a	34	c	35	d
36	c	37	a	38	a	39	d	40	d
41	d	42	d	43	d	44	d	45	b
46	c	47	a	48	a	49	b	50	d
51	a	52	b	53	d	54	b	55	c
56	b	57	a	58	a	59	b	60	b
61	d	62	c	63	d	64	d	65	c
66	c	67	a	68	d	69	d	70	b
71	b	72	b	73	d	74	c	75	b
76	d	77	a	78	a	79	a	80	a
81	b	82	a	83	d	84	b	85	a
86	c	87	c	88	b	89	c	90	a
91	d	92	d	93	a	94	d	95	b
96	a	97	b	98	d	99	c	100	a
101	b	102	d	103	b	104	a	105	c
106	a	107	d	108	a	109	b	110	b
111	c	112	c	113	d	114	a	115	d
116	d	117	c	118	a	119	d	120	b
121	d	122	c	123	b	124	a	125	a
126	b								

### Critical Thinking Questions

1	c	2	b	3	d	4	c	5	a
6	d	7	c	8	d	9	d	10	b
11	b	12	b	13	b	14	b	15	d
16	c	17	c	18	b	19	d	20	d
21	d	22	a	23	c	24	c	25	b
26	b								

### Assertion and Reason

1	c	2	c	3	e	4	b	5	c
6	e	7	b	8	e	9	b	10	c

## S Answers and Solutions

### Photosynthetic and consumer protists

- (a) Free floating living protist are collectively called plankton, which are float on the water surface.
- (c) Because in sea ecosystem, phytoplanktons are primary producers, if they are destroyed, naturally food chain will be disturbed.
- (c) The slime moulds are included into the division myxomycota by mycologists. The spores of slime moulds (acellular) germinate to produce biflagellate swarm cells which function as gametes.

- (c) Capillitium is a branched system of five tubes present in acellular slime moulds. Elaters and pseudoeaters are present in some bryophytes where as capitulum is a type of inflorescence.
- (c) They are unicellular, photosynthetic, eukaryotes.
- (b) Red tides of oceans are due to excessive growth of dinoflagellates like *Gymnodinium* and *Gonyaulax*.
- (b) Slime moulds are consumer protist.
- (c) In slime moulds the multinucleate protoplasm of a sporangium, undergoes cleavage to form spores.
- (d) The cells of dinoflagellate are generally covered by theca or lorica. Theca contains two grooves, the longitudinal groove called sulcus and transverse groove known as cingulum or annulus or girdle.
- (b) By binary fission the cells of *Paramecium* divide transversely. In conjugation two paramecia come in contact in the region their oral groove and establish protoplasmic bridge.
- (c) *Enterobius vermicularis* is a member of Nematelminthes.
- (c) Auxospores are generally called rejuvenescent cells because they help in increasing diatom size to normal one. Auxospores are commonly formed from zygote.
- (d) Mixotrophic nutrition is found in *Euglena*, when light is available it is photosynthetic in darkness, it is saprophytic.
- (a) Frustule of diatoms is made of silica, cellulose and pectic compounds.
- (d) *Amoeba* and *Paramecium* are protozoan protist while dinoflagellates are photosynthetic protist.

### Protozoan protists

- (d) Parapodia is the locomotory organ of *Nereis* (Annelida).
- (b) Animals of class sarcodina or rhizopoda have pseudopodia as locomotory organ.
- (c) Being unicellular, no specific excretory system develop so this function can be performed by plasmalemma by diffusion process.
- (b) Pseudopodium is formed due to different viscosity of sol and gel.
- (c) Members of this class are exclusively endoparasites.
- (c) *Amoeba* was discovered by Rossenhoff (1755) and described by H.I. Hirshfield.
- (d) Conjugation is shown by *Paramecium* which strictly belongs to ciliata of Protozoa.
- (a) Maurer's dots are green coloured structure which are found in erythrocytic cycle of *Plasmodium falciparum*.
- (d) Protists are primitive single celled organism with well organised nucleus, which shows auto as well as heterotrophic mode of nutrition.
- (d) *Amoeba* is omnivorous and its mode of nutrition is holozoic. It feeds by phagocytosis. *Amoeba* captures and engulfs its prey by means of pseudopodia.
- (a) Import involves passive sinking of food into body by rupture of plasmalemma, e.g., ingestion of algae.
- (b) Micronucleus is usually spherical, with a nuclear membrane and with diploid number of chromosomes. It controls the reproductive activities of the organism.

50. (d) *Trichonympha* is a symbiont in alimentary canal of termites. *Trichonympha* secretes cellulose digesting enzyme  $\beta$  glucosidase which convert cellulose into glucose.
54. (b) Single contractile vacuole is found in fresh water *Amoebae*. It appears like a bubble of clear, watery fluid, enclosed within a delicate and elastic condensation membrane resembling plasmalemma. Its function is osmoregulation, i.e., excess amount of water collected in it and discharged out by it. The water collected in contractile vacuole contain trace of ammonia.
56. (b) While female *Anopheles* suck the infected blood then various phases of malaria parasite reach in their stomach, where digestive enzymes digest all phases besides gametocyte.
61. (d) Magna (Trophozoite) stage of *Entamoeba histolytica* feeds on mucus and RBC.
64. (d) Absence of contractile vacuole in *E. histolytica* is a distinguish feature from *Amoeba*.
65. (c) The cilia of extreme posterior end are longer and form a bunch called caudal tuft.
66. (c) When kerosine, paraffin and petroleum oil is sprinkling over pond, then larva and pupa of mosquito die after some time due to difficulty of breathing. Difficulty of breathing is known as asphyxia.
68. (d) During favourable conditions, *Paramecium* commonly reproduces by transverse or horizontal binary fission which is at right angles to the longitudinal axis of the body. *Paramecium* stops feeding and oral groove and buccal structures begin to disappear. The micronucleus starts dividing by the complicated process of mitosis. After separation of daughter micronuclei, the macronucleus divides amitotically.
73. (d) Diatoms (chrysophytes) body is look like soap box and fit together.
75. (b) *Trypanosoma* belongs to phylum protozoa. *Trypanosoma gambiense* is unicellular and causes African sleeping sickness in man. This is parasite and lives in the blood stream and lymph glands of infected person in early stage of disease.
- Among animals *Euglena* contains chlorophyll and therefore, photo autotrophic in nature. *Euglena* is considered as connecting link between plants and animals. Few animals secrete digestive enzymes directly into their food outside the body and they are called saprozoic e.g., spiders, housefly etc.
80. (a) Infection depends upon intake of food or water contaminated with faecal matter containing tetranucleated cyst of *E. histolytica*.
81. (b) Malarial parasite is digenetic because its life cycle completed in two different hosts. Primary or principal host is man and secondary intermediate or vector host is female *Anopheles*.
85. (a) Both type of gamete are formed during sexual cycle, which occurs in female *Anopheles*.
88. (b) Two different type of nucleus, present in ciliata group are micronucleus and macronucleus. Micronucleus take part in reproduction while macronucleus is large kidney shaped which control metabolism.
90. (a) *Entamoeba coli* inhabits human colon and feed only bacteria and debris which are present there. Hence *Entamoeba coli* neither harmful nor beneficial.
92. (d) *Amoeba* will move away from contact with a foreign object or a probe while crawling or resting.
93. (a) Metacyclic form is a infective stage of *Trypanosoma gambiense* which are formed in lumen of salivary gland.
94. (d) All animals of sporozoa are endoparasite, so they have no any locomotory organs. It is a parasitic adaptation.
98. (d) Sporozoites are spindle or sickle shaped and uni-nucleated organism capable of wriggling movement. Each has a covering form but elastic pellicle containing longitudinal contractile microtubule.
103. (b) Asexual cycle passed in man by process termed schizogony (schizogony in liver and R.B.Cs). Schizogony is a type of multiple fission.
109. (b) Haemozoin is yellow brown to blackish and insoluble polymer of ferriprotoporphyrin. It is formed by haematin or breakdown product of haemoglobin. It collect in various tissues, e.g., spleen, skin.
113. (d) Tetranucleate (= Quadri) cyst is infected stage of *Entamoeba histolytica*. Infection is oral through contaminated food and water.
114. (a) *Leishmania donovani* is the parasite of kala-azar or dum-dum fever. These parasite is transmitted by sand fly.
115. (d) *Leishmania tropica* produce skin ulcers known as oriental sore or Delhi sore, which is spread by sand fly.
126. (b) The cell walls of diatoms are embedded with silica and thus the walls are indestructible.

### Critical Thinking Questions

1. (c) The major function of contractile vacuole is osmoregulation, i.e., removal of excess of water.
5. (a) *Amoeba* responds to light, positive behaviour towards moderate lights, negative behaviour to strong light and darkness.
6. (d) Haemozoin liberated in blood plasma.
8. (d) Paroxysm is the actual attack of malaria which Initially begins after a few earliest erythrocytic cycles, but it is, then repeated after every cycle. Obviously paroxysm result due to sufficient accumulation of haemozoin and other toxins in blood.
9. (d) The motile zygote formed by fertilization of macrogamete by a microgamete is called ookinete. It occurs in gut of mosquito.
10. (b) According to pressure or ectoplasmic concentration or sol-gel theory, pseudopodia are formed and withdrawn due to cyclic viscosity change in the colloidal cytoplasm from 'sol to gel' and 'gel to sol' states.
11. (b) Gametocyte is infective stage for female anopheles mosquito because optimum temperature for growth of gametocyte is present in their body.
12. (b) Initial stage of cyst formation, two or more transparent rod like structure are present in cytoplasm called chromatid bodies. These chromatid bodies are made of ribonucleoprotein.
13. (b) During starvation, *Amoeba* stops producing pseudopodia and covered with hard impervious and chitinous protective layer or cyst wall for the protection and survival as well as dispersal of *Amoeba*.
14. (b) The patient displays symptoms of malaria fever after a period of 8-10 days from infectious bite.
16. (c) *Amoeba* move, when cytoplasm change from sol to gel or gel to sol state

17. (c) In malaria chill and fever is due to the release of haemozoin, a toxic substance formed by breakdown of haemoglobin present in RBC. It will be released after the rupture of RBC, in erythrocytic schizogamy.
19. (d) The cryptomerozoite formed during pre-erythrocytic schizogony may enter the human RBCs to start the erythrocytic schizogony, while some of them enter new liver cells and reproduced asexually to give rise to a large number of meta-cryptomerozoites few are smaller in size and called micro-meta-cryptomerozoites.
20. (d) Gametocytes of malarial parasite are developed from merozoites in RBCs of man
23. (c) Infected R.B Cs rupture that merozoites and haemozoin granules are liberated in blood. Haemozoin granules are toxic and bring about fever.
25. (b) Babesiosis is caused by sporozoan protozoan- babesia. In this disease haemoglobinuric fever occur
26. (b) They are solitary unicellular or colonial unicellular eukaryotic organisms.
5. (c) Contractile vacuole in *Amoeba* is a single, clear rounded pulsating structure which is filled with a watery fluid and enclosed by a unit membrane. It helps in the osmoregulation and excretory activities. Digestion in *Amoeba* occurs in the food vacuoles. These are spherical species small and large, contain water and food in various phases of digestion. As soon as the egestion of non digestible food occurs through body these get disappear.
6. (e) Person suffering from amoebic dysentery has repeated blood mixed, slimy and foul smelling motions and causes the disease known as amoebic dysentery or amoebiasis. This protist feeds on red blood corpuscles by damaging the wall of large intestine and reaching the blood capillaries.
7. (b) Some erythrocytic merozoites enter fresh RBCs. And form rounded gametocytes (gamonts). The gametocytes are of two types – (i) Smaller male gametocytes or microgamete and (ii) Larger female gametocytes or macrogametocytes.
8. (e) The sexual phase of the malarial parasite occurs in the *Anopheles* mosquito. As the female *Anopheles* mosquitoes feed on blood, only they can serve as vector hosts of malarial parasites. The parasite does not harm the mosquito.
9. (b) When the mosquito bites man, sporozoites present in the salivary gland of female *Anopheles* mosquito are injected into the blood of the man. The erythrocytic schizont gives rise to merozoites. Malaria fever occurs when schizonts in red blood corpuscles burst and set free their contained merozoites and malarial pigment (haemozoin) in the blood plasma. Bursting of schizonts tends to be synchronous as they all burst at the same time. Haemozoin is said to be toxic and so includes high fever and shivering (Haemozoin is an unused heme, which is produced by the breakdown of haemoglobin). It is yellow brown to blackish in colour.
10. (c) Schizogony is an asexual reproduction in which schizont is formed. From the human blood sporozoites enter the liver cells. The sporozoite grows in size to become a rounded schizont called cryptozoite. The latter divides to form cryptomerozoites. The cryptomerozoites formed during pre-erythrocytic schizogony may enter the human RBCs to start the erythrocytic schizogony, while some of them enter new liver cells to repeat hepatic (liver) schizogony.

### Assertion and Reason

1. (c) Slime moulds exhibit alternation of generation. The diploid *plasmodium* is a sporophyte. Under certain conditions it bears sporangia. The sporangia bearing *plasmodium* and spore producing sporangia constitute the sporophyte generation. It is diplophase reduction division takes place at the time of differentiation of resting spore. The resting spores germinate to produce the haploid, uninucleate swarm cells or myxamoebae. The latter meet and fuse in pairs to form a zygote. The haploid resting spores and the swarm cells or myxamoebae represent the haploid or gametophyte generation.
2. (c) *Leishmania donovani* causes kala-azar. The parasite is transmitted by sandfly. The parasite lives inside the cells of liver, spleen, lymph glands, white blood corpuscles and inner wall cells of blood capillaries. In sleeping sickness disease, the parasite damages the brain.
3. (e) *Trichomonas vaginalis* inhabits vagina of women and causes the disease known as leucorrhoea. In males the parasite produces irritation in urethra. *Trichomonas buccalis* resides in the buccal cavity, which is nearly harmless.
4. (b) *Euglena* is a typical example of mastigophora. It is phytoflagellate as it possesses both chloroplast and flagella. It is autotrophic in sunlight, but becomes heterotrophic in dark. Because of its two fold nutritional abilities, it is usually studied as a plant as well as an animal. But it is more an animal than plant because of
  - (a) The absence of cellulose cell wall overlying the plasma membrane.
  - (b) Presence of centriole forming blepharoplasts.
  - (c) Reserve food is paramylon which is not a true starch.
  - (d) Response to various stimuli like an animal.

## Protista (Unicellular eukaryotes)

## Self Evaluation Test

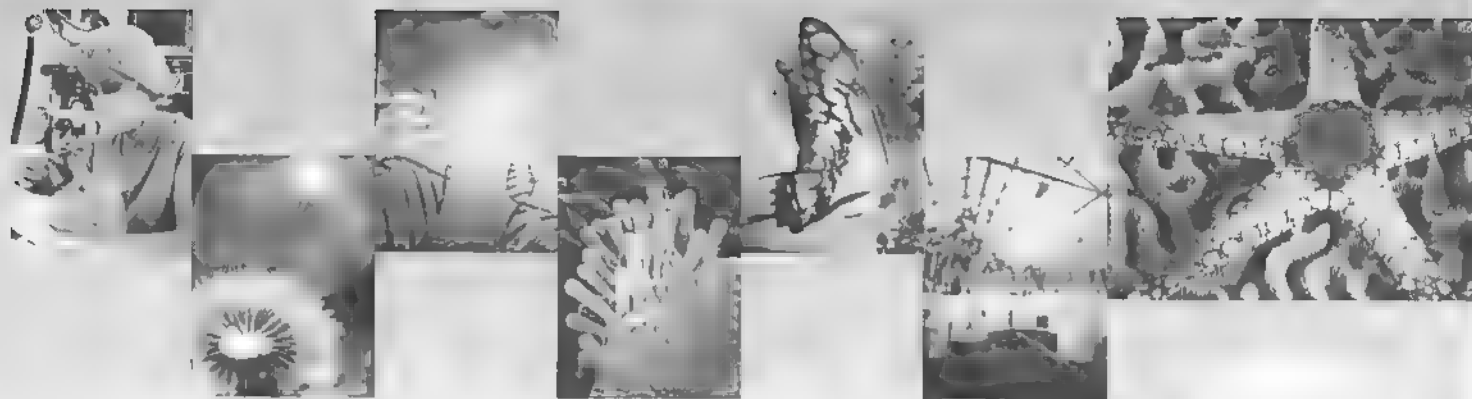
1. During endocytosis, [KCET 2009]
  - (a) The cell divides its cytoplasm during mitosis
  - (b) The cell digests itself
  - (c) The cell engulfs and internalises materials using its membrane
  - (d) The cell enables the extracellular digestion of large molecules
2. Cell wall are well preserved as fossils in one of the following
  - (a) Dinophyceae (b) Bacillariophyceae
  - (c) Cyanophyceae (d) Euglenophyceae
3. The chief advantage of encystment to an *Amoeba* is [CBSE PMT 2003]
  - (a) The chance to get rid of accumulated waste products
  - (b) The ability to survive during adverse physical conditions
  - (c) The ability to live for some time without ingesting food
  - (d) Protection from parasites and predators
4. In which of the following animal dimorphic nucleus is found [CBSE PMT 2002]
  - (a) *Amoeba proteus* (b) *Plasmodium vivax*
  - (c) *Paramecium caudatum* (d) *Trypanosoma gambiense*
5. *Amoeba* is called Immortal and it is scattered all over the world due to [CPMT 1999]
  - (a) Conjugation (b) Regeneration
  - (c) Binary fission (d) Sexual reproduction
6. Mode of feeding in free living protozoans is [DPMT 2007]
  - (a) Holozoic (b) Saprozoic
  - (c) Both (a) and (b) (d) None of these
7. Select the matching pair
  - (a) *Giardia* – diarrhoea (b) *Plasmodium* – pyorrhoea
  - (c) *Leishmania* – dysentery (d) *Trypanosoma* – kala-azar
8. In *Trypanosoma gambiense*
  - (a) Reproduction is by multiple fission
  - (b) There are two nuclei, a micronucleus and a macronucleus
  - (c) There are two locomotory organelles, a flagellum and an undulating membrane
  - (d) Tse-tse fly has no role to play in life cycle
9. *Trypanosoma* finally invades
  - (a) Brain (b) Liver
  - (c) Blood (d) Cerebrospinal fluid
10. These organisms are fungus like in one phase of their life cycle and *Amoeba* like in another phase of their life cycle [AIIMS 2009, 13]
  - (a) Diatoms (b) Slime molds
  - (c) Dinoflagellates (d) Water molds
11. Which infective stage of the plasmodium contained by the female Anopheles that transfer into human body and causes malaria [MP PMT 2011]
  - (a) Mesozoites (b) Gametocyte
  - (c) Sporozoite (d) Schizont
12. In patient suffering from malaria, the cells having Schuffner's granules are
  - (a) Gametocytes (b) Signet ring trophozoites
  - (c) Infected erythrocytes (d) Infected liver cells
13. Which is true about *Trypanosoma* [CBSE PMT 1990; Odisha JEE 2005]
  - (a) Polymorphic (b) Monogenetic
  - (c) Facultative parasite (d) Non-pathogenic
14. The type of nutrition present in *Entamoeba* is [Odisha JEE 2010]
  - (a) Saprozoic (b) Parasitic
  - (c) Autotrophic (d) None of these
15. Common trait between *Amoeba* and leucocyte is
  - (a) Encystment (b) Pseudopodia
  - (c) Sporulation (d) Contractile vacuole
16. Which is correct [DPMT 2007]
  - (a) Slime moulds are haploid
  - (b) Protozoan lack cell wall
  - (c) Dinoflagellates are immotile
  - (d) Pellicle is absent in *Euglena*
17. *Amoeba* takes food through [RPMT 1995]
  - (a) Phagocytosis (b) Pinocytosis
  - (c) Endocytosis (d) All the above
18. Which is absent in amoeba [RPMT 1996]
  - (a) Golgi apparatus (b) Lysosome
  - (c) Centriole (d) Plasmalemma
19. *Amoeba* sticks to substratum by means of [RPMT 1996]
  - (a) Rough surface (b) Plasmalemma
  - (c) Protein (d) None of the above
20. In *Plasmodium*, diploid stage is [APMEE 1996]
  - (a) Oocyst (b) Gamont
  - (c) Schizont (d) Sporozoite
21. *E. histolytica* does not show [CPMT 2010]
  - (a) Binary fission (b) Budding
  - (c) Encystation (d) Excystation
22. Just as *Xenopsylla* is to *Yersinia pestis*, so is [AIIMS 2003]
  - (a) *Glossina palpalis* to *Wuchereria bancrofti*
  - (b) *Culex* to *Plasmodium falciparum*
  - (c) *Homo sapiens* to *Taenia solium*
  - (d) *Phlebotomus* to *Leishmania donovani*
23. Hyaline cap in *Amoeba* is formed [RPMT 1999]
  - (a) Around food vacuole
  - (b) Around contractile vacuole
  - (c) Around nucleus
  - (d) In front of pseudopodium
24. Binary fission in *Amoeba* involves [RPMT 1999]
  - (a) Amitosis (b) Mitosis
  - (c) Meiosis (d) None of these
25. Which animal exhibits sexual dimorphism [RPMT 1999]
  - (a) Lobosa (b) Ciliata
  - (c) Sporozoans (d) Radiolarians

26. During conjugation in *Paramecium* [BHU 1999; Pb. PMT 2004; AFMC 2012]  
 (a) Out of the four micronuclei formed, three nuclei degenerate  
 (b) Out of the twelve macronuclei formed, four nuclei degenerate  
 (c) Zygote nucleus undergoes eight successive divisions in each conjugant  
 (d) Out of the sixteen nuclei formed from zygote, 12 become macronuclei and 4 micronuclei
27. In humans, schizont stage of *Plasmodium* is found in [MP PMT 2003]  
 (a) Liver cells only  
 (b) Liver, spleen and blood cells  
 (c) RBCs and liver cells  
 (d) RBCs only
28. Malaria parasite harm liver cells [RPMT 1999]  
 (a) In erythrocytic cycle (b) After erythrocytic cycle  
 (c) Before erythrocytic cycle (d) None of these
29. Select the mismatch [NEET 2017]  
 (a) *Frankia* – *Alnus*  
 (b) *Rhodospirillum* – *Mycorrhiza*  
 (c) *Anabaena* – Nitrogen fixer  
 (d) *Rhizobium* – Alfalfa
7. (a) *Giardia intestinalis* causes Diarrhoea.
9. (d) *Trypanosoma* is usually found in the blood of vertebrates, finally invading cerebrospinal fluid.
10. (b) The cellular slime moulds are now classified with the Amoebas because of their evolutionary closeness and these slime moulds have cellular amoeboid stage. The other phyla of slime moulds are the plasmodial slime moulds or Myxomycota.
13. (a) *Trypanosoma* is polymorphic and has four forms : *Leishmania*, *Leptomonad*, *Crithidia* and *Trypanosomal* stages.
16. (b) Protozoans are acellular eukaryotic organisms included in the division protista. They are basically animals previously included under nonchordates. As because they are animals they lack any cell wall. Cell wall is present in plant cells outside cell membrane. The main function of the cell wall is to provide mechanical strength
18. (c) The structures presents in *Amoeba* are pseudopodia, plasmalemma, nucleus, contractile vacuole, Food vacuole, water globules, endoplasmic reticulum, ribosomes, golgi bodies, mitochondria, lysosomes and microtubules
19. (b) Plasmalemma possesses numerous fine, ridge-like extension on its outer surface. Due to presence of these it have adhesive properties and serve to bind the animalcule to the substratum.
20. (a) The motile diploid zygote formed by fertilization (anisogamy) of macrogamete by a microgamete is called ookinete. Ookinete penetrates the stomach wall and forms encysted zygote called oocyst or sporont.
23. (d) Pseudopodium at its forward end gets its firm consistency by hyaline cap which is made of ectoplasm.
26. (a) The diploid micronucleus of each conjugant divides by meiosis. Thus, 4 haploid daughter micronuclei are produced of which 3 degenerates in each conjugant, while the remaining one divides by mitosis 2 unequal pronucleus.
27. (c) Schizont is a stage in the history of malarial parasite occurring in RBCs and liver cells.
28. (c) The first cycle of *plasmodium* occurs in liver cells which is harm for liver cell because sporozoite phagocytes the cytoplasm of the liver cells

## Answers and Solutions

1	c	2	b	3	b	4	c	5	c
6	c	7	a	8	d	9	d	10	b
11	c	12	c	13	a	14	b	15	b
16	b	17	d	18	c	19	b	20	a
21	b	22	d	23	d	24	b	25	a
26	a	27	c	28	c	29	b		

3. (b) *Amoeba* forms a cyst and reproduces by multiple fission, during adverse environmental condition.
4. (c) *Paramecium caudatum* shows nuclear dimorphism. There are two type of nuclei – a large bean shaped polyploid vegetative nucleus called macronucleus and a small rounded diploid reproductive nucleus known as micronucleus.
5. (c) *Amoeba* reproducing by binary fission, the parent becomes wholly merged in the offspring. Thus, there exists a continuity of life, so that amoeba is potentially immortal and it is scattered all over the world.



## Chapter

# 1.4

## Fungi (Multicellular decomposers)

The terms 'fungus' has been derived from the Latin word which means mushroom. The science dealing with the study of fungi is called as mycology. Clausius (1601) may be regarded as one of the earliest writers to describe fungi. The term 'Fungus' was coined by Gaspard and Bauhin. Bauhin (1623) also included the account of known fungal forms in his book *Pinax Theatric Botanica*. Kingdom fungi has been called mycota by Von Arx (1981) and mycetae by Alexopoulos. Anton de Bary is known as 'Father of Modern Mycology and plant pathology'.

**Famous Indian Mycologists :** Dastur, Mundkar, Prof. K.C. Mehta (associated with study of annual recurrence of wheat rust in India), Thind, Srinivasan, K.G. Mukherji, Chaudhary and Sadasivan are other famous mycologists of India

### Thallus organization

The plant body of true fungi (Eumycota) is **thallus**. It may be non-mycelial or mycelial. The non-mycelial forms are unicellular, however, they may form a **pseudomycelium** by budding. In mycelial forms, the plant body is made up of thread like structures called hyphae (sing. hypha). The mycelium may be **aseptate** (non-septate) or **septate**. When non-septate and multinucleate, the mycelium is described as **coenocytic**. In lower fungi the mycelium is non-septate e.g., Phycomycetes. In higher forms it is septate e.g., Ascomycetes, Basidiomycetes and Deuteromycetes. In some forms the plant body is unicelled at one stage and mycelial at the other. Their organization is sometimes described as **dimorphic**.

When the entire mycelium is converted into reproductive structure, the thallus is described as **holocarpic**. However, if only a part of it becomes reproductive, the thallus is called as **eucarpic**.

### Specialised formation

In higher forms the mycelium gets organised into loosely or compactly woven structure which looks like a tissue called **plectenchyma**. It is of two types :

**Prosenchyma :** It comprises loosely woven hyphae lying almost parallel to each other.

**Pseudoparenchyma :** If the hyphae are closely interwoven, looking like parenchyma in a cross-section, it is called as pseudoparenchyma.

In addition to above, the fungal mycelium may form some specialized structures as under :

**Rhizomorphs :** It is a 'root or string-like' elongated structure of closely packed and interwoven hyphae. The rhizomorphs may have a compact growing point.

**Sclerotia :** Here the hyphae gets interwoven forming pseudoparenchyma with external hyphae becoming thickened to save the inner ones from desiccation. They persist for several years.

**Stroma :** It is thick mattress of compact hyphae associated with the fruiting bodies.

### Cell organization

The cell wall of fungi is mainly made up of chitin ( $C_{22}H_{54}N_4O_{21}$ ) and cellulose. While chitin is a polymer of N-acetyl glucosamine, the cellulose is polymer of d-glucose. Precisely, the cell wall may be made up of cellulose-glucan (oomycetes), chitin-chitosan (Zygomycetes), mannan-glucan (Ascomycetes), chitin-mannan (Basidiomycetes) and chitin-glucan (some Ascomycetes, Basidiomycetes and Deuteromycetes). Besides, the cell wall may be made up of cellulose-glycogen, cellulose-chitin or polygalactosamine-galactan.

The cell wall is closely associated with the inner layer, the plasma membrane. In fungi, plasma membrane bears coiled membranes outgrowth called **lomasomes** (Moore and McAlear, 1961).

Fungi cells are eukaryotic. They possess all eukaryotic organelles such as mitochondria, E.R., ribosomes, microbodies, lysosomes, vacuoles and reserve food particles (glycogen, lipid etc.). Golgi body or dictyosome are also not typical. In many cases they are **unicisternal**. The cells lack chloroplast. However, a reddish pigment, **neocercosporin** has been isolated from the fungus *Cercospora kikuchii*. The vacuoles are bound by tonoplast. The genetic material is DNA.

Fungi possess true nucleus having definite nuclear envelope. The nuclear envelope persists during nuclear division. It has called **karyochorisis** by Moore (1965). The nuclear spindle is formed within the nuclear envelope in both mitosis and meiosis. The spindle poles either contain centrioles or spindle pole bodies (SPB) but lack microtubular organization.

### Nutrition

The fungi are achlorophyllous organisms and hence they can not prepare their food. They live as heterotrophs i.e., as parasites and saprophytes. Some forms live symbiotically with other green forms.

**Parasites** : They obtain their food from a living host. A parasite may be **obligate** or **facultative**. The obligate parasites thrive on a living host throughout their life. The facultative parasites are in fact saprophytes which have secondarily become parasitic.

**Saprophytes** : They derive their food from dead and decaying organic matter. The saprophytes may be **obligate** or **facultative**. An obligate saprophyte remains saprophytic throughout its life. On the other hand, facultative saprophyte is in fact a parasite which has secondarily become saprophytic.

**Symbionts** : Some fungal forms grow in symbiotic association with the green or blue-green algae and constitute the **lichen**. A few fungal forms grow in association with the roots of higher plants. This association is called as **mycorrhiza**.

### Reproduction

#### (1) Vegetative reproduction

**Fragmentation** : Some forms belonging to Ascomycotina and Basidiomycotina multiply by breakage of the mycelium.

**Budding** : Some unicelled forms multiply by budding. A bud arises as a papilla on the parent cell and then after its enlargement separates into a completely independent entity.

**Fission** : A few unicelled forms like yeasts and slime moulds multiply by this process.

#### (2) Asexual reproduction

**Oidia** : In some mycelial forms the **thallus** breaks into its component cells. Each cell then rounds up into a structure called **oidium** (pl. **oidia**). They may germinate immediately to form the new mycelium, e.g., *Rhizopus*.

**Chlamydospores** : Some fungi produce chlamydospores which are thick walled cells. They are intercalary in position. They are capable of forming a new plant on approach of favourable conditions, e.g., *Rhizopus*, *Saprolegnia*, *Ustilago*.

**Sporangiospores** : These are thin-walled, non-motile spores formed in a sporangium. They may be uni- or multinucleate. On account of their structure, they are also called as **aplanospores**, e.g., *Rhizopus*, *Mucor*.

**Zoospores** : They are thin-walled flagellate spores which occur in aquatic fungi. These spores are formed in a zoosporangium. The zoospores are of several types :

- ☐ Uniflagellate with whiplash type flagellum e.g., *Allomyces*.
- ☐ Uniflagellate with tinsel type flagellum e.g., *Rhizidiomyces*.
- ☐ Biflagellate with a tinsel type and a whiplash type flagella e.g., *Saprolegnia*.
- ☐ Biflagellate with two whiplash type flagella e.g., *Plasmodiophora*.

**Conidia** : In some fungi the spores are not formed inside a sporangium. They are born freely on the tips of special branches called **conidiophores**. The spores thus formed are called as **conidia**, e.g., *Penicillium*.

(3) **Sexual reproduction** : With the exception of Deuteromycetes (fungi imperfecti), the sexual reproduction is found in all groups of fungi. During sexual reproduction the compatible nuclei show a specific behaviour which is responsible for the onset of three distinct mycelial phases. The three phases of nuclear behaviour are as under :

**Plasmogamy** : Fusion of two protoplasts.

**Karyogamy** : Fusion of two nuclei.

**Meiosis** : The reduction division.

These three events are responsible for the arrival of the following three mycelial phases :

**Haplophase** : As a result of meiosis the haploid ( $n$ ) or haplophase mycelium is formed.

**Dikaryotic phase** : The plasmogamy results in the formation of dikaryotic mycelium ( $n + n$ ).

**Diplophase** : As a result of karyogamy the diplophase mycelium ( $2n$ ) is formed.

**The fungi reproduce sexually by the following methods**

☐ **Planogametic copulation** : In this type of copulation fusion occurs between flagellate gametes. It is of three types :

(i) **Isoplanogametic copulation** : Both the fusion gametes are similar and flagellate, e.g., *Synchytrium*.

(ii) **Anisoplanogametic copulation** : The fusing gametes are flagellate, similar in structure but different in size. In which one is small and other one is large, e.g., *Allomyces*.



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(iii) **Ooplanogametic copulation** : It is union between a small flagellate male gamete and a large nonflagellate food laden female gamete or ovum. e.g., *Monoblepharella*.

□ **Gametangial contact** : It involves fusion of two gametangia. In lower forms the female gametangium is called as **oogonium**. The male gametangium is termed as **antheridium**. A contact develops in between the two gametangia and then the male nucleus is transferred into the female directly or through a tube. e.g., *Phytophthora*, *Albugo*.

□ **Gametangial copulation** : In this case the fusion occurs in between the two gametangia. When it occurs in some holocarpic forms where the entire thallus acts as gametangium, the phenomenon is called as **hologamy**. In others, dissolution of cell wall in between the two gametangial brings about gametangial copulation. e.g., *Rhizopus*, *Mucor*.

□ **Spermatization** : Here the uninucleate male gametes called **spermatia** are formed in special structures called **spermogonia** or **pycnidia**. The female gametangium is called as **ascogonium** which has a long neck called **trichogyne**. The spermatium attaches itself with the trichogyne and transfers the male nucleus, thus bringing about **dikaryotisation**. e.g., *Puccinia graminis*

**Somatogamy** : In higher fungi there is reduction of sexuality to the maximum level. Here two hyphae of opposite strains are involved in fusion thus bringing about **dikaryotization**. e.g., *Penicillium brefidianum*, *Agaricus*.

### Clamp connection

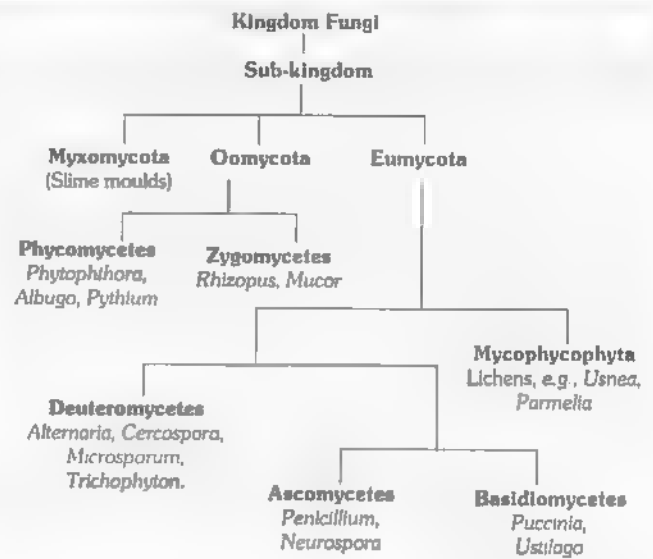
In Basidiomycetes, the dikaryotic cells divide by **clamp connections**. They were first observed by Hoffman (1856) who named it as '**Schnallenzenellen**' (buckle-joints). A lateral pouch like outgrowth arises which projects downward like a hook. This pouch or **clamp** becomes almost parallel to the parent cell. The two nuclei now undergo conjugate division in such a way that one spindle lies parallel to the long axis of the cell and the other somewhat obliquely. As a result, one daughter nucleus enters into the clamp

### Heterothallism

Blakeslee, (1904) while working with *Mucor* sp. observed that in some species sexual union was possible between two hyphae of the same mycelium, in others it occurred between two hyphae derived from 'different' spores. He called the former phenomenon as **homothallism** and the later as **heterothallism**. Thus, the homothallic species are self-fertile whereas the heterothallic are self sterile. In heterothallic species the two 'thalli' are sexually incompatible. They are said to belong to opposite strains. Blakeslee designated them as + and - i.e., belonging to opposite strains or mating types. Bipolar heterothallism found in *Mucor* and *Rhizopus*.

### Classification

The classification of fungi based on the characteristics of the life cycle involved like nature of somatic phase, kinds of asexual spores, kinds of sporangia, nature of the life cycle and presence or absence of perfect or sexual stage.



### Important features of classes

(1) **Phycomycetes (Oomycetes/Algal fungi)** : It is also called lower fungi, mycelium is coenocytic. Hyphal wall may contain chitin or cellulose (e.g., *Phytophthora*). Asexual reproduction occurs with the help of conidio-sporangia. Under wet conditions they produce **zoospores**. Under dry conditions, the sporangia directly function as conidia. Zoospores have heterokont flagellation (one smooth, other tinsel). Sexual reproduction is oogamous. It occurs by gametangial contact where male nucleus enters the oogonium through a conjugation tube. The fertilized oogonium forms oospore. e.g., *Saprolegnia*, *Albugo* (*Cystopus*), *Phytophthora*, *Pythium*, *Sclerospora*, *Peronospora*, *Plasmopara*

(2) **Zygomycetes (Conjugation fungi)** : Mycelium is coenocytic. Hyphal wall contains chitin or fungal cellulose. Motile stage is absent. Spores (*Sporangiospores/Aplanospores*) are borne inside sporangia. Sexual reproduction involve fusion of coenogametes through conjugation (Gametangial copulation). It produces a resting diploid Zygospore. On germination, each zygospore forms a germ sporangium at the tip of a hypha called promycelium e.g., *Mucor*, *Rhizopus*, *Pilobolus*, *Abscidia*, *Saksenea*.

(3) **Ascomycetes (Sac fungi)** : These are unicellular as well as multicellular fungi. In the latter, mycelium is septate. The asexual spores formed in chains are called conidia. The spores are formed exogenously, i.e., outside sporangium. They detach from the parent and form new mycelia. Sexual reproduction is through ascospores, which are formed endogenously (within the mycelium) in a sac like structure called **ascus** (pl. asci). Ascus arranged either in linear order (*Neurospora*) or unorderedly (e.g., *Yeast*). The gametes involved in sexual reproduction are nonmotile compatible and are generally represented as + and -. The fusion of gametes is followed by reductional division that produces haploid ascospores.

The fruiting body called **ascocarp**. Genus *penicillium* belong to this e.g., *Erysiphe*, *Claviceps*, *Clan*,

The ascocarp are of four types :

(i) **Cleistothecium** : It is an ovoid or spherical fruiting body which remains completely closed e.g., *Aspergillus*, *Penicillium*.

(ii) **Perithecium** : It is a flask shaped fruiting body which opens by a single pore called **ostiole**. e.g., *Neurospora*.

(iii) **Apothecium** : It is a saucer-shaped fruiting body. The asci constitute the fertile zone called **hymenium** e.g., *Peziza*.

(iv) **Ascstroma** : It is not a distinct fruiting body. It lacks its own well defined wall. The asci arise directly with a cavity (locule) of stroma. It is also called as **pseudothecium** e.g., *Mycosphaerella*.

(4) **Basidiomycetes (Club fungi)** : They are the most advanced fungi and best decomposers of wood. These are called club fungi because of a club shaped end of mycelium known as basidium. They have septate multinucleated mycelium. Septa possess central dolipores and lateral clamp connections. The sexual spores called basidiospores are generally four in number. They are produced outside the body (exogenous) unlike ascomycetes where they are endogenous. Two compatible nuclei fuse to form zygote, which undergoes meiosis and forms four basidiospores. The fruiting body containing basidia is a multicellular structure called **basidiocarp**. The common members are edible mushrooms (*Agaricus*), smut (*Ustilago*) and rust (*Puccinia*).

(5) **Deuteromycetes (Fungi imperfecti)** : The group include all those fungi in which sexual or perfect stage is not known. Mycelium is made of septate hyphae. Asexual reproduction commonly occur by means of conidia. e.g., *Alternaria solani*, *Fusarium*, *Gibberella*, *Colletotrichum falcatum*, *Helminthosporium oryzae*, *Cercospora personata*.

## Economic Importance

### (1) Harmful aspects

**Crop diseases** : Several important crop plants are destroyed by fungal diseases. Some important ones are listed here under :

Table : 1.4-1 Fungal disease in plants

Disease	Causal organism
White rust of crucifers	<i>Albugo candida</i> or <i>Cystopus candidus</i>
Early blight of potato	<i>Alternaria solani</i>
Tikka disease of groundnut	<i>Cercospora personata</i>
Ergot disease of rye	<i>Claviceps purpurea</i>
Red rot of sugarcane	<i>Colletotrichum falcatum</i>

Powdery mildew of wheat	<i>Erysiphe graminis</i>
Powdery mildew of pea	<i>Erysiphe polygoni</i>
Leaf spot of oats	<i>Helminthosporium avenae</i>
Brown leaf spot of rice*	<i>Helminthosporium oryzae</i>
Covered smut of barley	<i>Ustilago hordei</i>
Loose smut of wheat	<i>Ustilago tritici</i>
Late blight of potato**	<i>Phytophthora infestans</i>
Downy mildew of grapes	<i>Plasmopara viticola</i>
Black rust of wheat	<i>Puccinia graminis-tritici</i>
Brown rust of wheat	<i>Puccinia recondita</i>
Yellow rust of wheat	<i>Puccinia striiformis</i>
Damping off of seedlings	<i>Pythium sp.</i>
Wart disease of potato	<i>Synchytrium endobioticum</i>
Covered smut of jowar (Sorghum)	<i>Sphacelotheca sorghii</i>

\*Severe famine of Bengal (1943) which caused death of a large number of people was due to this disease.

\*\*Famous famine of Ireland (1845) is associated with this disease which caused death of lakhs of people.

**Diseases in human beings** : Some important ones are :

Table : 1.4-2 Fungal disease in human

Disease	Causal organism	Place of infection
Athletes foot	<i>Epidermophyton floccosum</i>	Foot
Ring worm	<i>Trichophyton sp.</i> , <i>Microsporum sp.</i>	Skin
Moniliasis	<i>Candida albicans</i>	Nails
Aspergillosis	<i>Aspergillus niger</i> , <i>A. flavus</i> , <i>A. terreus</i>	Lungs
Tonulosis	<i>Cryptococcus neoformans</i>	Lungs, CNS

**Spoilage of food** : Some forms like *Rhizopus*, *Mucor*, *Aspergillus*, *Cladosporium* grow on food articles and spoil them. *Cladosporium* grows even at a temperature of  $-6^{\circ}\text{C}$ .

**Aflatoxins** : They are produced mainly by *Aspergillus flavus* and *A. parasiticus*. They are well known for their carcinogenic effect. e.g., Aflatoxin  $B_1$ ,  $B_2$ ,  $M_1$ ,  $M_2$ ,  $G_1$ ,  $G_2$ .

**Poisonous fungi** : Some fungi are extremely poisonous e.g., *Amanita phalloides* ('death cup'), *A. verna* and *Boletus satanas*. Forms like *Coprinus*, *Psilocybe* are less poisonous. The fungus *Amanita phalloides* produces toxins like  $\alpha$ -amanitin, phalloidin etc. which are very poisonous.

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**Ergotism** : The fungus causing 'ergot' disease of rye (*Secale*) is *Cleviceps purpurea*. It contains many poisonous alkaloids in their sclerotia. It causes poisoning in human beings. It's acute condition is called as 'St. Anthony's fire'.

**Hallucinogenic drugs** : The hallucinogenic drug LSD (Lysergic acid diethylamide) is extracted from *Cleviceps purpurea* as also from *Inocybe*. Besides, the mushroom *Amanita muscaria* is also hallucinogenic.

**Rotting of wood** : Rotting of wood is caused due to degradation of lignin and cellulose. It is brought about fungi like *Polyporus* sp., *Fomes* sp. and *Ganoderma* sp., Forms like *Fusarium*, *Penicillium* leave stains on the wood.

**Allergies** : Spores of *Mucor*, *Aspergillus*, *Penicillium*, *Puccinia* etc., present in the atmosphere cause allergies.

**Deterioration of articles** : Forms like *Aspergillus*, *Cladosporium*, *Rhizopus*, *Chaetomium*, *Alternaria* deteriorate cork, rubber, leather, textile and even plastics.

### (2) Useful aspects

**Food** : Forms like *Agaricus bisporus*, *Agaricus campestris*, *Podaxon*, *Prodaxia*, *Morchella esculenta*, *Lentinus edodes*, *Clavatia gigantea*, *Volvariella volvacea* are edible. The yeast *Saccharomyces cerevisiae* is used for making 'yeast cake', when mixed with cereal flour, the yeasts produce a preparation called **incaparina**. The **Single Cell Protein (SCP)** obtained from yeasts, *Penicillium*, *Fusarium* etc. are used as substitute of protein food. *Rhizopus oligosporus* when processed with soyabeans yield a food preparation called '**tempeh**'. It has high protein contents.

**Organic acids** : Several organic acids are commercially produced by fungi, some of which are given hereunder :

**Table : 1.4-3 Fungi as a source of organic acids**

Organic acids	Source
Citric acid	<i>Aspergillus niger</i>
Gallic acid	<i>Penicillium glaucum</i>
Gluconic acid	<i>Aspergillus niger</i> , <i>Penicillium purpurogenum</i>
Fumaric acid	<i>Rhizopus stolonifer</i> , <i>Mucor</i> sp.
Lactic acid	<i>Rhizopus nodosus</i>
Kojic acid	<i>Aspergillus flavus</i>
Oxalic acid	<i>Aspergillus niger</i>

**Flavouring of food** : *Penicillium roquefortii* and *P. camemberti* are employed for flavouring cheese.

**Brewing and baking** : Yeasts are generally used in bakeries and breweries. e.g., *Saccharomyces cerevisiae*.

**Antibiotics** : The antibiotics are chemicals produced by living organisms that kill other living organisms. The first known antibiotic is **penicillin** that was extracted from *Penicillium notatum* by A. Flemming, (1944). Raper (1952) also extracted the same antibiotic from *P. chrysogenum*. Besides, several other antibiotics have been extracted since then.

**Table : 1.4-4 Fungi as a source of antibiotics**

Antibiotics	Source
Griseofulvin	<i>Penicillium griseofulvum</i>
Cephalosporin	<i>Acremonium</i> sp.
Ramycin	<i>Mucor ramannianus</i>
Jawaharin	<i>Aspergillus niger</i>
Patulin/Clavacin	<i>A. patulum/ A. clavatus</i>
Fumigallin	<i>Aspergillus fumigatus</i>
Frequentin	<i>Aspergillus cyclospium</i>
Chloromycetin	<i>Streptomyces venezuelae</i>

**Other chemicals** : Various chemicals have been obtained from different kinds of fungi. Yeast are good source of glycerol and enzymes like zymase, invertase and lipase. Cellulases are obtained from *Aspergillus*. Some alkaloids are also obtained from fungi e.g., Ergotinine, Ergotetrine and Ergobasine from *Cleviceps purpurea*. Gibberellins (plant hormones) are obtained from *Gibberella fujikuroi*. Another hormone, trisporic acid is obtained from *Mucor mucedo*.

**Biological assays** : The fungi can detect the presence of certain chemicals present in the medium even in traces e.g., *Aspergillus niger* for Mn, Pb, Zn, Cu, Mo etc.

**Vitamins** : Various vitamins have been obtained from different kind of fungi.

**Table : 1.4-5 Fungi as source of vitamins**

Vitamins	Source
Vitamin A	<i>Rhodotorula gracilis</i>
Vitamin B <sub>2</sub>	<i>Eremothicum ashbyii</i>
Thiamine B <sub>1</sub>	<i>Saccharomyces cerevisiae</i>
Riboflavin B <sub>2</sub>	<i>Saccharomyces cerevisiae</i>

**In biological control** : Soil inhabiting fungus *Trichoderma* kills *Pythium* fungus (root rot fungus). Similarly *Penicillium Vermiculatum* checks *Rhizoctonia solani*.

Many species of *Neurospora* have been used as convenient organisms for genital and biochemical studies. *Neurospora* is also known as *Drosophila* of plant kingdom.

## Description of some important fungus

### *Rhizopus/Mucor*

**Habitat :** They are cosmopolitan and saprophytic fungus, living on dead organic matter. *Rhizopus stolonifer* occur very frequently on moist bread, hence commonly called **black bread mold** *Mucor* is called **dung mold**. Both are called **black mold** or **pin mold** because of black coloured pin head like sporangia. Besides, it appears in the form of white cottony growth on moist fresh organic matter, jams, jellies, cheese, pickles, etc.

**Structure :** The vegetative body or thallus consists of well branched, aseptate and multinucleate (coenocytic) mycelium on the surface of substratum. The mature mycelium is distinguishable into three types of hyphae :

(1) **Stoloniferous hyphae (Stolons) :** These hyphae grow horizontally on the surface of substratum. They are relatively stout and less branched than other hyphae. Certain portions of the stolons called nodes, give out rhizoids and sporangiophores.

(2) **Rhizoidal hyphae :** They arise in clusters from the lower side of each node and are repeatedly branched. The rhizoids penetrate the substratum and serve as anchors for the superficial mycelium. These hyphae secrete enzymes like amylase and maltase into the substratum and absorb the digested food.

(3) **Sporangiophores :** They are erect, aerial, unbranched reproductive hyphae that arise in clusters from the upper side of each node. Each sporangiophore develops single terminal sporangium which is filled with spores. In *Mucor* there is no such distinction. In *Mucor*, the hyphae develop singly. There is no holdfast or apparant node. The hyphal wall is made up of chitin or fungus cellulose, a polymer of glucosamine ( $C_8H_{13}O_5N$ )<sub>n</sub>.

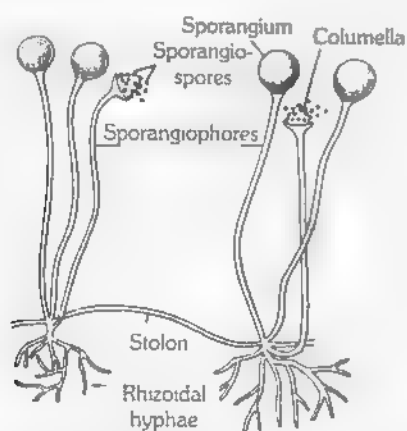


Fig : 1.4-1 *Rhizopus* – Habit sketch showing stolon, rhizoidal hyphae and sporangiophores

**Reproduction :** They reproduce by vegetative, asexual and sexual methods

(1) **Vegetative reproduction :** It takes place by fragmentation. If stolon breaks accidentally into small segments, each part grows into a new mycelium.

(2) **Asexual reproduction :** It occurs by three types of non-motile mitospores, sporangiospores, chlamydospores and oidia.

**Sporangiospores :** The sporangiospores are also called **aplanospores**. They are thin walled, non-motile, multinucleate spores formed in a sporangium. A vertically growing mycelium acts as sporangiophore. Its tip now shows accumulation of food and nuclei. A septum now appears separating the **outer sporangium** from the **inner columella**. The sporangium dehisces irregularly due to collapse of columella and the spores are dispersed.

**Chlamydospores :** These are the perennating spores formed when the fungus starts facing dry conditions. The protoplasm of hyphae collects at certain places, rounds off accumulates a lot of food materials and develops thick wall to become chlamydospores.

**Arthrospore or Oidia :** In liquid, sugary and acidic pH medium the hyphae of *Rhizopus* and *Mucor* undergo septation and form small rounded reproductive cells called oidia. They multiply by budding like yeast. The budded condition is called **torula stage**. It takes part in alcoholic fermentation. On transfer to a suitable solid medium, each oidium forms a new mycelium.

(3) **Sexual reproduction :** Sexual reproduction takes place by conjugation between two multinucleate but single celled gametangia. The gametes are isogamous and non-motile.

The species of *Rhizopus* may be **heterothallic** (*R. stolonifer*) or **homothallic** (*R. sexualis*). But mostly heterothallic in both *Mucor* and *Rhizopus*. In homothallic species sexual union is brought about between two hyphae of the same mycelium whereas in heterothallic species it occurs between two hyphae derives from different compatible strains i.e., positive (+) and negative (–).

The two mycelial branches growing towards each other are called **progametangia**. Their tips become rich in food and nuclei. They enlarge and come in contact with each other. A septum is laid down separating the terminal **gametangium** from the proximal **suspensor**. The gametangium has dense cytoplasm and many nuclei whereas the suspensor has vacuolated cytoplasm with fewer nuclei. Each gametangium behaves as an coenogamete. The two gametangia fuse with each other. **Plasmogamy** is followed by pairing of nuclei of opposite strains. The unpaired nuclei degenerate. This is followed by **karyogamy**. The **zygospore** so formed develops a dark coloured thick wall and undergoes rest. It is also believed that karyogamy is delayed till the germination of zygospore.

On the arrival of favourable conditions the zygospore germinate. The outer wall ruptures and the inner protrudes out in the form of promycelium. The promycelium grows vertically upward and forms a terminal **germsporangium**. It is generally believed that meiosis occurs in the germ sporangium. Each diploid nucleus forms four haploid nuclei, of which three degenerate.

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Occasionally, failure of gametangial copulation results in parthenogenous development of zygospores which are called **azygospore** (parthenospores).

Life cycle is haplobiontic.

### Economic Importance

(1) **Spoilage of food** : Exposed bread and other food particles are spoiled by *Rhizopus*.

(2) **Soft rot** : *Rhizopus* species attack sweet potato, apple and strawberry producing soft rot or leak disease. Germinating maize grains are also attacked.

(3) **Mucormycosis** : *Mucor pusillus* and *M. ramosissimus* may attack internal human organs, including lungs alimentary canal and nervous system.

(4) **Fermented foods** : Temph (a solid food from soyabean) and sufu (chinese cheese) are prepared with the help of *Rhizopus* and *Mucor* respectively.

(5) **Chemicals** : Citric acid prepared by *Mucor* from molasses, fumaric acid and cortisone by *Rhizopus stolonifer*, Lactic acid by *R. stolonifer* and *R. nodosus* and alcohol by *R. oryzae* and *M. javanicus*.

### Yeast

**Habitat** : Yeast is a saprophytic fungus of ascomycetes, found on substratum which is rich in sugars e.g., sugarcane, juice, fruits (palms, grapes), milk etc. Some species are found on animal excreta.

**Structure** : Yeast was first described by Anton Van Leeuwenhoek in 1680. Yeast are nonmycelial or unicellular, which is very small and either spherical or oval in shape. However, under favourable conditions they grow rapidly and form **false mycellum** or **pseudomycellum**. Individual cells are colourless but the colonies may appear white, red, brown, creamy or yellow. The single cell is about 10  $\mu\text{m}$  in diameter. The cell is surrounded by a rigid cell wall which is having proteins (7.8%), lipids (8.5 – 13.5%), Chitin (1 – 2%). Besides, there are 2 important polysaccharides glucan (30 – 35%) and mannan (about 30%).

Yeasts are facultative aerobes i.e., they are anaerobes but can also survive under aerobic conditions and respire aerobically as well. The yeast cells secrete extracellular enzyme **zymase** which converts complex sugars into simple soluble sugars that can easily be assimilated.

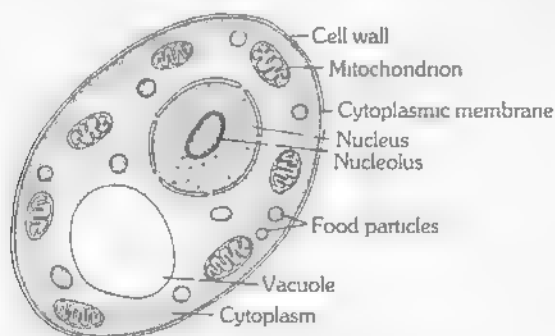


Fig : 1.4-2 Electron micrograph of single yeast cell

**Reproduction** : Yeast reproduces by vegetative or asexual and sexual methods

(1) **Vegetative reproduction** : Yeast reproduce vegetatively either by budding or by fission.

**By budding** : It is the common method of reproduction in yeasts (e.g., *Saccharomyces*) under favourable conditions (i.e., when growing in sugar solution). During this process a small bud like out growth appears at one end of the parent cell which gradually enlarges in size (unequal division of cytoplasm takes place) The nucleus enlarges and divides **amitotically** into two daughter nuclei.

**By fission** : It is a common method of reproduction in yeasts (e.g., *Schizosaccharomyces*). During fission the parent cell elongates and its nucleus divides into two daughter nuclei. The two nuclei separate apart. It is followed by a transverse cytokinesis by formation of a transverse septum which develops centripetally. The two cells separate apart and behave as uninucleate vegetative thalli.

(2) **Sexual reproduction** : Sexual reproduction in yeast takes place during unfavourable conditions, particularly when there is less amount of food.

The sex organs are not formed in yeasts and the sexual fusion occurs between the two haploid vegetative cells or two ascospores which behave as gametes. The two fusing gametes are haploid and may be **isogamous** or **anisogamous**. Such kind of sexual reproduction is called **gametic copulation**. It is the best example of **hologamy** i.e., the entire vegetative thallus is transformed into reproductive body. The sexual fusion leads to the formation of diploid zygote. The zygote behaves as an ascus and forms 4 – 8 haploid ascospores after meiosis. These liberate and function as vegetative cells.

**Guillermond** (1940) has recognised three types of life cycle in yeasts.

(1) **Haplobiontic life cycle** : This type of life cycle is common in *Schizosaccharomyces octosporous*, a homothallic species.

(2) **Diplobiontic life cycle** : This type of life cycle is found in *Saccharomyces ludwigii*.

(3) **Haplodiplobiontic life cycle** : This type of cycle is found in *Saccharomyces cerevisiae* in which haploid and diploid both types of generations are found.

In addition to above, in *Schizosaccharomyces pombe*, two adjoining sister cells fuse and this phenomenon is called **adelphogamy**. In some yeasts e.g., *Debaryomyces*, the mother and daughter cells fuse to form the zygote and this phenomenon is called **pedogamy**.

### Economic Importance

#### Useful activities

(1) **Baking industry** : Yeast are used in manufacture of bread. Kneaded flour is mixed with yeast and allowed to ferment. Yeast convert starch into sugars and sugar into  $\text{CO}_2$  and alcohol

with help of enzyme zymase,  $\text{CO}_2$  is released when effervescence takes place due to which bread become spongy and gets swollen and is of light weight.

2) **Brewing industry** : Brewer's yeast or Baker's yeast is *Saccharomyces cerevisiae* and wine yeast is *Saccharomyces ellipsoidens*. They perform alcoholic fermentation.



(3) **Food yeast** : Yeast from brewing industry is harvested and used as food yeast. It is rich in protein and vitamins-B (Riboflavin). Special food yeasts are *Torulopsis* (protein), *Endomyces* (fat) and *Cryptococcus* (both).

#### Harmful activities

(1) Fermentation of fruits and fruit juices by yeast cells makes their taste unpleasant.

(2) Parasitic species of yeast like *Nematospora* causes diseases in tomato, cotton and bean.

(3) Parasitic yeast cause diseases in human beings (e.g., cryptococcosis, blastomycosis and torulosis).

### Albugo

**Habitat** : *Albugo* is a member of phycomycetes. It is an obligate parasite and grows in the intercellular spaces of host tissues. It is parasitic mainly on the members of families Cruciferae, Compositae, Amaranthaceae and Convolvulaceae. The disease caused by this fungus is known as **white rust or white blisters**.

The most common and well known species is *Albugo candida* which attacks the members of the mustard family (Cruciferae). It is commonly found on *Capsella bursa pastoris* (Shepherd's purse) and occasionally on radish, mustard, cabbage, cauliflower, etc. The reserve food is oil and glycogen.

**Structure** : The plant body of the fungus is mycelial and eucarpic. The mycelium is intercellular, branched, aseptate and multinucleate (coenocytic). The mycelium produces finger like or globular haustoria which enter into the host cells to absorb the food material. The mycelial wall is made up of cellulose-glucan.

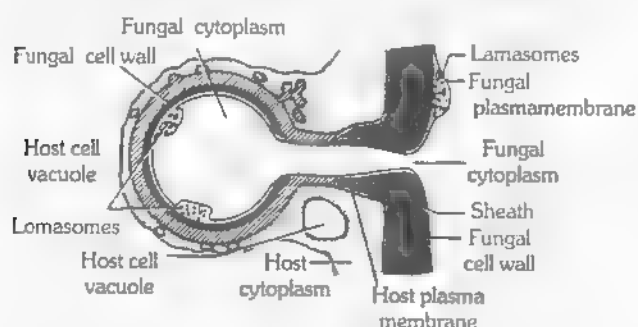


Fig : 1.4-3 *Albugo* – Ultra structure of haustorium (diagrammatic)

**Reproduction** : The fungus *Albugo* reproduces asexually as well as sexually.

(1) **Asexual reproduction** : Asexual reproduction takes place by the formation of sporangia or conidia. The fungal mycelium collects below the host epidermis and forms sporangiophores (conidiophores). These are club-shaped and multinucleate. The sporangiophores cut sporangia in basipetal manner, that is, the oldest and first formed are at the top and the youngest and last formed are at the base.

If water is available sporangia forms about 4 – 12 (usually eight) zoospores within two minutes of their formation. The zoospores are kidney shaped and laterally biflagellate (unequal).

If water is not available, the sporangia germinate directly by forming germ tubes.

(2) **Sexual reproduction** : The sexual reproduction is oogamous type and takes place with the help of **antheridia** and **oogonia**. The antheridia and oogonia are multinucleate in the beginning but become uninucleate by disorganization of nuclei. The antheridia are club-shaped and the oogonia are globular. Both sex organs develop terminally on the hyphae. There is a single egg (oosphere) surrounded by periplasm. At the time of fertilization, a **receptive papilla** develops on one side of the oogonium through which the fertilization tube enters into the oogonium. Inside the oogonium the male nucleus fuses with the egg nucleus. The diploid zygote develops a warty wall and becomes the **oospore**. The diploid nucleus undergoes meiosis, followed by several mitotic divisions. After a period of rest, the oospore germinates and produces reniform, biflagellate (dissimilar and laterally) zoospores. The zoospores are first released into a vesicle and then to the outside. They swim for some time, encyst and then germinate to form germ tubes. Most part of the life cycle of *Albugo* is **gametophytic**. The sporophytic phase is limited only to the oospore stage.

### Aspergillus (Psalliotia)

(1) *Aspergillus* is the common laboratory weed which also grows on a number of food stuffs.

(2) *A. oryzae* is used to prepare alcohol by saccharification of rice starch.

(3) *A. niger* is used to produce citric acid from molasses.

(4) *A. oryzae* and *A. niger* are also used for production of various enzymes.

(5) *A. flavus* is a serious health hazard because of their toxic effect on food caused by secretion of 'aflatoxin' in contaminated food.

(6) Some species cause aspergillosis, a disease in man and animals.

### Agaricus

(1) *Agaricus* is a group of macrofungi that grows in rich organic matter. They are commonly known as **mushrooms**.

(2) **Habitat** : They grow in rich organic soil. During rainy season they are abundantly found in shady places growing on rotten logs of tree trunks.

(3) **Structure** : The mature plant body of the fungus is divided into two parts.

(i) **Vegetative mycelium** : The vegetative mycelium runs hidden in soil. This **perrenating stage** after somatogamy becomes dikaryotic called as **rhizomorph**

(ii) **Fruit body** : It is formed during rainy season. The above ground part of the fungus is generally referred to as **sporophore or basidiocarp**. It is the most conspicuous part of the fungus. The binucleate mycelium of the soil gives rise to the sporophore. The sporophore is divided into two parts.

□ **Stipe or stalk** : It is the basal part of the sporophore consisting of cylindrical fleshy body having pinkish white colour.

□ **Pileus or cap** : It is umbrella shaped. It is formed by swelling of the tip of stipe. On the ventral side develops hymenial layers of gills from the centre towards periphery.

Internally gill is also composed of pseudoparenchymatous tissue distinguished into :

(i) **Trama** : The central part

(ii) **Sub-hymenium** : Located on both sides of trama and is sterile

(iii) **Hymenium** : Fertile layers bearing basidia

(4) **Reproduction** : Only type of reproduction is somatogamy between two negative and positive strains of somatic hyphae which results in formation of dikaryotic rhizomorph. Rhizomorph forms fruit body which bears basidia. Each basidium has two nuclei of different strains which undergo fusion forming diploid nucleus. This nucleus undergoes meiosis to form four nuclei two of +ve and two of -ve strain. The nuclei are pushed into four finger like projections called as **sterigmata**. Nuclei are pushed into each sterigmata so as to form **basidiospores**. They are thrown on the substratum where they germinate to haploid vegetative hyphae.

5) **Economic importance of *Agaricus*** : A *bisporus* and *A. campestris* are edible.

### Lichens

The term lichen was first given by Theophrastus for superficial growth on bark of *Olea europea* (olive) tree. A lichen is structurally organised entity consisting of the permanent association of a fungus and an alga. The fungal component of a lichen is called **mycobiont** (mostly ascomycetes) and the algal component is called **phycobiont** (mostly blue-green alga). The fungus provides the structural covering that protects alga from unfavourable conditions, i.e., drought, heat etc. It also traps moisture from the atmosphere and anchors the lichens to a substrate. The alga prepares organic food (e.g., mannitol) by the process of photosynthesis from carbon dioxide. If the algal component is a cyanobacterium (blue-green alga), it fixes atmospheric nitrogen in addition to preparation of food. The relationship between the two is that of consortium, symbiosis or mutualism. Crombie (1885) gave the **master and slave hypothesis** for this association (also called husband and wife association) and in this association fungal partner is having upper hand. It is also known as **helotism**. Micheli (1729) describe 300 species of lichens. Dual nature of lichen was studied by Schwendener (1897). Ahmadjian (1963)

considers fungus to be a controlled parasite. The phenomenon of controlled parasitism is called **helotism**. The study of lichen is called **lichenology**

**Habitat** : Lichens are cosmopolitan in distribution. Their growth is very slow. Some lichens growing in arctic regions are believed to be 4500 year old. The lichens which grow on stones are called **saxicolous** (e.g., *Dermatocarpon*) and those growing on barks of tree are called **corticolous** (e.g., *Usnea*, *Parmelia*, *Graphis*). Some lichen developing on wood are called **lignicolous** (e.g., *Cyphelium*) and those growing on soil are called **terricolous** (e.g., *Cladonia*, *Lecidea*). A few lichens are aquatic (e.g., *Peltigera*, *Verrucaria margacea*). The lichens generally do not grow near smoky industrial areas where atmosphere is polluted. *Cladonia rangiferina*, commonly known as **reindeer-moss** grows luxuriantly in tundra region and form the food of animals like the reindeer and caribou (musk ox).

**Classification** : Hole (1967) divided lichens into 3 classes :

(1) **Ascolichens** : When fungal partner belongs to ascomycetes. Most lichens are ascolichens. Ascolichens are further divided into :

**Gymnocarpeae** : Fruiting body is apothecium.

**Pyrenocarpeae** : Fruiting body is perithecium.

(2) **Basidiolichen** : When the fungal partner belongs to basidiomycetes.

(3) **Lichen Imperfecti** : When the fungal component belongs to fungi imperfecti.

#### Structure

(1) **External structure** : The lichens vary in their size and shape. However, three main types are recognised on the basis of their habit, growth, form and mode of occurrence.

(i) **Crustose or Crustaceous lichens** : These lichens occur as crust over rocks, soil or tree barks, e.g., *Graphis*, *Haematomma*.

(ii) **Foliose or Folioseous lichens (Leafy lichens)** : They are leaf like lobed structure which are attached to substratum by rhizoid like organs, e.g., *Parmelia*, *Peltigera*.

(iii) **Fruticose or Filamentous lichens** : They are branched shrubby lichens but small base e.g., *Cladonia*, *Usnea*.

(2) **Internal structure** : The bulk portion of lichen thallus is formed by fungal partner. The alga constitutes about 5% of the lichen body. Internally the lichens are of two types .

(i) **Homoiomerous thalli** : Algal cells and fungal hyphae are uniformly dispersed throughout the thallus, e.g., *Collema*.

(ii) **Heteromerous thalli** : The algal cells are restricted to algal zone only. In these forms fungal component is dominant. Usually the heteromerous thalli show 4 distinct zones.

(a) **Upper cortex** : Formed by compactly interwoven hyphae either without interspaces between them or interspaces filled with gelatinous substances. A cuticle like layer is present on the surface. In some species e.g., *Parmelia* breathing pores are present.

(b) **Algal layer** : Present just below the upper cortex forming photosynthetic zone of the thallus. This layer is also called **gonidial layer**.

(c) **Medulla** : Occurs nearly in the middle of the thallus beneath the algal layer, the hyphae are loosely interwoven in this layer, *Parmelia*, *Graphis*.



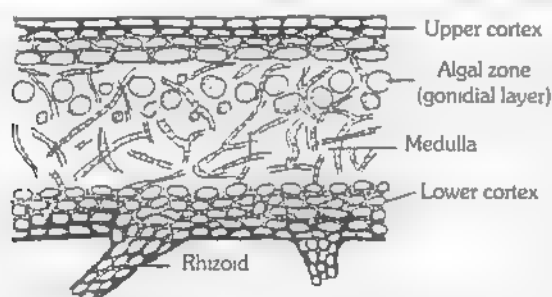


Fig : 1.4-4 Transverse section of a foliose lichen

(d) **Lower cortex** : Comprising of closely packed dark coloured hyphae rhizoids arise from this layer.

**Special structures and Propagules** : The following specialized structures and propagules are associated with lichen thalli.

(1) **Breathing pores** : The upper surface of some lichens, particularly the foliose lichens is provided with pores. Here the fungal hyphae are loosely arranged. They help in aeration.

(2) **Cyphellae** : Loosely arranged areas in lower cortex are cyphellae and these also help in gaseous exchange. Cyphellae are analogous to stomata of higher plants.

(3) **Cephalodia** : These are gall like outgrowths present on the upper surface of the thallus. They are distinguishable into cortex and medulla with similar fungal but different algal components from that of the main thallus. Lichens having two algal and one fungal partner are called **diphycolophilous**. The cephalodia are meant for retaining moisture e.g., *Peltigera*.

(4) **Isidia** : These are coral like, simple or branched outgrowths present on the upper surface of the thallus. They have the same algae and fungal component as that of the main thallus. They help in photosynthesis as also in vegetative propagation e.g., *Parmelia*, *Peltigera*.

(5) **Soredia** : It is a powdery mass comprising both algal and fungal components formed in a postule like structure called **soralium**. The soralia arise from the algal zone lying just below the upper cortex e.g., *Physcia*, *Parmelia*.

**Reproduction** : Lichens reproduce both by asexual and sexual methods.

#### (1) Asexual reproduction

**Fragmentation** : The main thallus breaks into small pieces which grow as independent thalli

**Rejuvenation** : Plants like *Cladonia* show this unique phenomenon. It becomes young again. The older parts of the thallus die whereas the young branches continue to grow.

**Conidia** : In several lichens the fungal component forms conidia on conidiophores. They form new fungal mycelium which with suitable algal component form the lichen.

**Pycniospores** : The conidia formed in a flask shaped structures lying embedded in the thallus (pycnidia) are called as pycniospores. The pycniospores form new fungal mycelium which constitute the lichen on coming in contact with suitable algal component.

(2) **Sexual reproduction** : Sexual reproduction in lichen is performed only or mainly by its fungal component. So, the structure of the reproductive organs is dependent upon the type of their fungal partner.

#### Economic importance

(1) **Pioneer of vegetation** : Lichens are considered as pioneers in initiating a plant succession on rocks. These are the first plant group which play an important role in the formation of the soil. So lichens are called as **formers of nature or soil builders**.

(2) **Food and Fodder** : Reindeer moss (*Cladonia rangiferina*) of the arctic region is used as food for reindeer and cattle. Iceland moss (*Cetraria islandica*) is ground up and mixed with wheat and made into cakes in Iceland. Rock tripe (*Umbilicaria*) has been eaten by travellers when they face starvation in arctic regions.

(3) **Medicinal uses** : Dog lichen (*Peltigera canina*) was used as medicine for hydrophobia in ancient days and Lungwort (*Lobaria pulmonaria*) was used for the diseases of lungs. Usnic acid obtained from *Usnea* (old man's beard) and *Cladonia* sp. is used as broad spectrum antibiotic. It is effective against gram positive bacteria. *Lobaria pulmonaria*, *Cetraria islandica* are used in respiratory diseases particularly T.B., *Roccella montagnei* in angina, *Parmelia saxatilis* in epilepsy and *Usnea barbata* in urinary troubles.

(4) **In perfumery** : *Ramalina* and *Evernia*, having sweet scented thalli, are used in the preparation of **Dhup, Havan Samagri** and **soap**. Perfumes are extracted from *Evernia prunastri* and *Lobaria pulmonaria*.

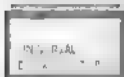
(5) **In tanning and dyeing** : Lichens like *Cetraria islandica* and *Lobaria pulmonaria* are used in tanning. A red dye is obtained from *Ochrolechia* sp. whereas *Parmelia* sp. yield a brown dye. Litmus used as acid-base indicator is obtained from *Roccella montagnei* and *Lasallia pustulata*. An **orchill** dye is obtained from *Roccella* and *Lecanora* which is purified as orcein and used as a biological stain.

(6) **In brewing and distilling** : The lichens contain carbohydrates in the form of **lichenin**. *Cetraria islandica* and *Cladonia rangiferina* (yield upto 66% of the polysaccharides) are used to obtain alcohol in Sweden and Russia.

(7) **Indicators of air pollution** : Lichens are very sensitive to  $\text{SO}_2$  and grow only in  $\text{SO}_2$  free atmosphere. So lichens like *Usnea* are used as indicators of air  $\text{SO}_2$  pollution.

(8) **As poison** : Some lichens are poisonous also such as *Letharia vulpina* due to **vulpinic acid**, *Cetraria juniperina* due to **pinastrinic acid**, *Parmelia molliuscula* due to **selenium**, *Xanthoria parietina* due to **beryllium** and *Evernia furfuracea* due to **chlorine**.

(9) **Other uses** : Some lichen yield important chemicals e.g., salazinic acid (*Ramalina siliquosa*), **Lecanoric acid** (*Parmelia subrudecta*) and **squamatic acid** (*Cladonia crispata*) etc. In hot season, *Usnea* gets dry and becomes highly inflammable. It easily catches fire and causes forest fires.



### Mycorrhizae

The term 'mycorrhizae' was coined by Frank (1885). It is an association between a fungus and the root of a higher plant e.g. Pine, Birch, *Eucalyptus*, *Ficus* etc. The actively growing roots of higher plants get infected by fungi. As a result, the roots are modified (i.e., become tuberous, nodulated, coralloid, etc.) to accommodate fungi. The root cells and fungi directly transmit nutrient substances to each other. Mycorrhiza is an example of **symbiosis** or **mutualism**.

**Types of mycorrhizae :** Mycorrhizae are classified into three categories :

(1) **Ectotrophic mycorrhiza :** It occurs only in about 3% of plant species, majority of which are forest trees, viz. pines, spurs, firs, oaks, beeches, birches, eucalyptus etc. The fungus partner is commonly a basidiomycetes. In this type of mycorrhizae, the fungus completely encloses the rootlet in a sheath or mantle of tissue formed of compact hyphal cells and penetrates only between the cells of root cortex. The ectomycorrhizal fungus cannot exist saprotrophically in nature without a plant host association. Such roots are devoid of root hair, root cap and may become unforked, bifurcate, nodular or coralloid.

(2) **Endotrophic mycorrhiza :** In this kind of mycorrhizae the fungus does not form an external mantle but lives within the root. The endomycorrhizae are further divided into three groups :

(i) **Ericaceous mycorrhizae :** The fungus forms dense intracellular coils in the outer cortical cells.

(ii) **Orchidaceous mycorrhizae :** These are associated with orchid roots. The fungus forms association from the time when the orchid seeds germinate.

(iii) **Vesicular-arbuscular mycorrhizae (VAM) :** The fungi of this group mostly belong to zygomycetes. This type is significant in agriculture because it occurs in a large number of crop plants. The fungal hyphae develop some special organs, called **vesicles** and **arbuscules**, within the root cortical cells.

(3) **Ectoendotrophic mycorrhiza :** This type of mycorrhiza sharing characteristics of both ecto and endotrophic mycorrhizas. The fungus forms a hyphal mantle and **Hartig net** as do the ectotrophic mycorrhiza and also establish haustoria and hyphae coils in the epidermal and cortical cells, like the ectotrophic mycorrhizas. The external hyphae deliver organic compounds absorbed from the humus to the root cells. One of the best studied examples of ectoendotrophic mycorrhizas is the mycorrhiza of *Monotropa indica*, the **Indian pine**.

### Advantages of mycorrhizal association

(1) The fungal hyphae increase a plant's uptake of certain nutrients from the soil, particularly phosphorus, copper, zinc, nitrogen and potassium.

(2) The mycorrhizal hyphae permeate the soil and help the absorption of water by host more efficiently.

(3) The mycorrhizal plants need less fertilizer and can even grow better on the infertile soils. They withstand high doses of heavy metals and acid rain pollution.

(4) The fungi produce various growth promoting substances which help the plants to grow better.

(5) Due to mycorrhizal association, the higher plants develop resistance to soil borne diseases (due to phytotoxins released by fungi), drought resistance and tolerate salinity, pH and temperature extremes.

## Tips & Tricks

☛ Poisonous mushrooms like *Amanita* are commonly called Toad stools.

☛ *Penicillium* is known as blue mould.

☛ Father of Indian mycology and Plant pathology : E.J. Butler.

☛ Smallest fungus : Yeast with a size of  $3-15\ \mu\text{m} \times 2-10\ \mu\text{m}$ .

☛ Nitrogen fixing fungi : Some species of *Rhodotorula* and *Saccharomyces*.

☛ Fungi inhabiting wood are known as ephylic.

☛ Autoecious fungus completes its life cycle on one host e.g., coffee rust (*Hamellia*). Heteroecious fungi require two hosts to complete their life cycle e.g., *Puccinia* (wheat rust).

☛ Fungi grow on tree are called as lignicolous fungi (*Polyporus*).

☛ Keratinophilic fungi appear on nails, feathers, hairs, hoofs.

☛ Biotrophic parasite (Gaumann, 1946). Absorbs nutrients from living host/cells.

☛ Necrotrophic parasite (Gaumann, 1946). Kills host cells for obtaining nourishment.

☛ Species of *Morchella* are commonly known as 'morels', 'sponge mushrooms' or 'gucchi'.

☛ Most suitable temperature for growth of mushrooms is 30 to 37°C.

☛ Bioactive molecule, cyclosporine A, that is used as an immunosuppressive agent in organ-transplant patients, is produced by the fungus *Trichoderma polysporum*.

- ✎ The species of *Polyporus* are commonly called 'bracket fungi' or 'self fungi'
- ✎ Phytoalexin are secreted by plants in response to fungal reactions. They are generally phenolic compound.
- ✎ Coprophilous fungi grow on dung e.g., *Pilobolus crystallinus*.
- ✎ Largest fungus is 'Giant puffball'.
- ✎ Dolipore septum : In Basidiomycetes, the septum becomes barrel shaped around a central pore. Dolipore septum may be surrounded by pore cap.
- ✎ Guinea pig of plant kingdom is *Aspergillus flavus*.
- ✎ Biobleaching : Fungus *Phanerochaete chrysosporium* can bleach paper pulp better than bleaching power.
- ✎ *Mycena* is a fungus that produces latex.
- ✎ Parasexuality in fungi was first described by G. Pontecorva and Ropers (1952) in *Aspergillus nidulans*.

## Ordinary Thinking

### Objective Questions

#### Fungi (General)

- The term 'fungus' was coined by  
(a) Gaspard Bauhin (b) De Bary  
(c) E.J. Butler (d) Sadasivan
- Who among the following is given the honour of "Father of Modern Mycology"  
(a) Stanley (b) Bawden  
(c) De Bary (d) Micheli
- Mycology (Mycetology) is a branch which deals with the study of  
(a) Viruses (b) Algae  
(c) Bacteria (d) Fungi  
[AMU (Med.) 1998; KCET 2000]
- Which of the following antibiotic is active against fungus  
(a) Streptomycin (b) Polyenes  
(c) Tetracycline (d) Neomycin  
[Odisha JEE 2008]
- Basidiospores are borne on the tip of  
(a) Mycelium (b) Ascocarp  
(c) Flagella (d) Aplanospore  
[Odisha JEE 2008]
- The highest number of species in the world is represented by  
(a) Fungi (b) Mosses  
(c) Lichens (d) Algae  
[CBSE PMT (Pre.) 2012; NEET 2013]
- Which one of the following matches is correct

[AIPMT (Cancelled) 2015]

(a)	<i>Alternaria</i>	Sexual reproduction absent	Deuteromycetes
(b)	<i>Mucor</i>	Reproduction by Conjugation	Ascomycetes
(c)	<i>Agaricus</i>	Parasitic fungus	Basidiomycetes
(d)	<i>Phytophthora</i>	Aseptate mycelium	Basidiomycetes

- A group of fungi with septate mycelium in which sexual reproduction is either unknown or lacking are classified under  
[NCERT; Pb. PMT 2000; JIPMER 2002; AFMC 2010]  
(a) Phycomycetes (b) Deuteromycetes  
(c) Ascomycetes (d) Basidiomycetes
- Fungal spores produced asexually at the tips of hyphae are called  
[AFMC 2005]  
(a) Sporangiothores (b) Anthospores  
(c) Conidiophores (d) Meiospores
- Match column I with column II and select the correct option

Column I (Kingdom)		Column II (Class)	
A.	Morels	1.	Deuteromycetes
B.	Smut	2.	Ascomycetes
C.	Bread mould	3.	Basidiomycetes
D.	Imperfect fungi	4.	Phycomycetes

[KCET 2007; Kerala PMT 2011; AIPMT 2015]

- (a) A-3, B-4, C-1, D-2 (b) A-2, B-3, C-4, D-1  
(c) A-4, B-1, C-2, D-3 (d) A-3, B-4, C-2, D-1  
(e) A-2, B-1, C-4, D-3
- All fungi can be called as  
[CBSE PMT 1993; CMC Vellore 1993; MP PMT 2000]  
(a) Heterotrophs (b) Autotrophs  
(c) Saprophytes (d) Parasites
- Which of the following does not contain chlorophyll  
(a) Fungi (b) Algae  
(c) Bryophyta (d) Pteridophyta
- Which of the following is famous mycologist of India  
(a) P. Maheshwari (b) M.O.P. Iyengar  
(c) K. Sharma (d) Sadasivan
- Who gave the parasitic nature of fungus in plants  
(a) Pasteur (b) Anton De Bary  
(c) Robert Koch (d) J.F. Kuhn
- Thread like filaments of fungi are known as  
[NCERT; Manipal 1995]  
(a) Conidia (b) Mycorrhiza  
(c) Sporangium (d) Hyphae
- In 1943 the causal organism and host of Bengal famine was  
[EAMCET 1995; BHU 1995, 2008]  
(a) Wheat rust by *Puccinia*  
(b) Blast of rice by *Pyricularia oryzae*  
(c) Blast of rice by *Xanthomonas oryzae*  
(d) Brown leaf spot of rice by *Helminthosporium oryzae*
- Destruction of 50% maize plants in USA (1970) due to infection of  
(a) *Hemileia vastratrix*  
(b) *Helminthosporium oryzae*  
(c) *Claviceps purpurea*  
(d) *Ustilago maydis*
- Choose the wrong statements  
[AIPMT 2015]  
(a) *Neurospora* is used in the study of biochemical genetics  
(b) Morels and truffles are poisonous mushrooms  
(c) Yeast is unicellular and useful in fermentation  
(d) *Penicillium* is multicellular and produces antibiotics

## 90 Fungi (Multicellular decomposers)

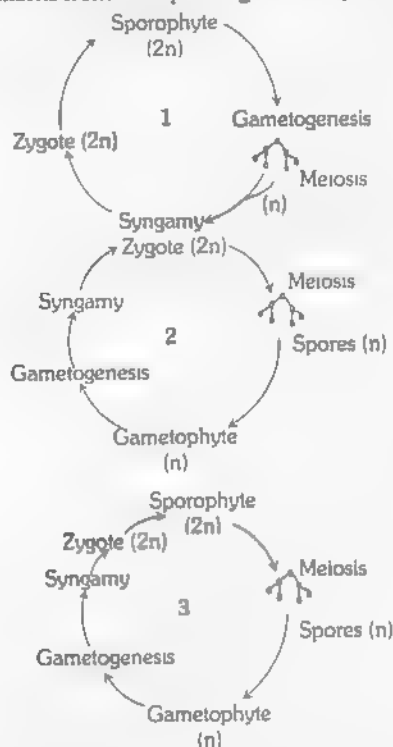
19. Which one of the following has haplontic life cycle  
[CBSE PMT 2009]  
(a) *Funaria* (b) *Polytrichum*  
(c) *Ustilago* (d) Wheat
20. The following is an example of saprophytes [KCET 1998]  
(a) Mushroom (b) Lichen  
(c) Unicellular algae (d) Ferns
21. The cell wall of fungi is made up of [NCERT; RPMT 1997, 99; CPMT 1998, 2009; MP PMT 2001; Odisha JEE 2004; NEET (Phase-I) 2016]  
(a) Chitin (b) Cellulose  
(c) Pectin (d) Suberin
22. Which one is the wrong pairing for the disease and its causal organism [CBSE PMT 2009]  
(a) Late blight of potato – *Alternaria solani*  
(b) Black rust of wheat – *Puccinia graminis*  
(c) Loose smut of wheat – *Ustilago nuda*  
(d) Root-knot of vegetables – *Meloidogyne sp*
23. Facultative saprophyte is  
(a) A parasite which can live as a saprophyte  
(b) Always a parasite  
(c) Always a saprophyte  
(d) May acquire parasitic mode of life
24. Which of the following is not correctly matched [AIIMS 1998]  
(a) Root knot disease – *Meloidogyne javanica*  
(b) Smut of bajra – *Tolysporium penicillariae*  
(c) Covered smut of barley – *Ustilago nuda*  
(d) Late blight of potato – *Phytophthora infestans*
25. The disease of potato responsible for famous famine of Europe was caused by or late blight of potato is caused by [RPMT 1997; CPMT 2000; BVP 2000; HPMT 2005; BHU 2006; DPMT 2007]  
(a) *Colletotrichum falcatum* (b) *Phytophthora infestans*  
(c) Potato mosaic virus (d) *Alternaria solani*
26. During the process of decomposition in which stage complex organic matter convert into inorganic ions and salts by fungi [GUJCET 2015]  
(a) Mineralization (b) Catabolism  
(c) Fragmentation (d) All of the above
27. When fungi feed on dead organic matter, they are known as [CPMT 1999]  
(a) Dimorphic (b) Parasites  
(c) Saprophytes (d) None of these
28. According to their modes of nutrition, the fungi are classified into [CBSE PMT 2000]  
(a) One category (b) Three categories  
(c) Four categories (d) Six categories
29. Which of the following divisions of fungi includes 'Club fungi' [KCET 2000]  
(a) Zygomycota (b) Ascomycota  
(c) Deuteromycota (d) Basidiomycota
30. Aflatoxins are produced by [MP PMT 2000, 12]  
(a) Bacteria (b) Viruses  
(c) Fungi (d) Nematodes
31. Wart disease caused by *Synchytrium endobioticum* is found in [JIPMER 2002]  
(a) Cabbage (b) Potato  
(c) Pea (d) Groundnut
32. Septum in eumycota fungi, bearing a complex pore is designated as a [BHU 2002]  
(a) Coenocyte (b) Septate hypha  
(c) Dolipore septum (d) Secondary simple pore
33. Which of the following secretes toxins during storage conditions of crop plants [CBSE PMT 2002]  
(a) *Fusarium* (b) *Penicillium*  
(c) *Aspergillus* (d) *Colletotrichum*
34. Which of the following produces spores, but lacks vascular structure [KCET 2002]  
(a) Pteridophytes (b) Gymnosperms  
(c) Fungi (d) Dicots
35. The hyphae of *Aspergillus* are [AFMC 2002]  
(a) Aseptate and multinucleate  
(b) Septate and multinucleate  
(c) Aseptate and uninucleate  
(d) Septate and uninucleate
36. Asexual reproduction in fungi takes place by [Odisha JEE 2010; BHU 2012]  
(a) Endospore (b) Gametangia  
(c) Exospores (d) Conidiospore
37. Gametangial copulation (conjugation) is common in  
(a) Zygomycetes (b) Ascomycetes  
(c) Phycomycetes (d) Deuteromycetes
38. Dikaryon formation is characteristic of  
(a) Ascomycetes and basidiomycetes  
(b) Phycomycetes and basidiomycetes  
(c) Ascomycetes and phycomycetes  
(d) Phycomycetes and zygomycetes
39. Plasmogamy is fusion of [NCERT; AIIMS 1997]  
(a) Two haploid cells including their nuclei  
(b) Two haploid cells without nuclear fusion  
(c) Sperm and egg  
(d) Sperm and two polar nuclei
40. Cellulose is the major component of cell walls of [CBSE PMT 2008]  
(a) *Pseudomonas* (b) *Saccharomyces*  
(c) *Pythium* (d) *Xanthomonas*
41. Chitin present in fungal wall has a formula [AMU (Med.) 1996; Chd. CET 1997]  
(a)  $(C_{22}H_{54}N_4O_{21})_n$  (b)  $(C_{21}H_{54}N_4O_{22})_n$   
(c)  $(C_{22}H_{54}N_4O_{13})_n$  (d)  $(C_{22}H_{28}N_4O_{21})_n$
42. A dikaryotic cell has [DPMT 1997]  
(a) Two haploid nuclei  
(b) Diploid zygotes  
(c) Two similar nuclei  
(d) Two dissimilar haploid nuclei
43. Algal fungi are placed in [MP PMT 1997]  
(a) Ascomycetes (b) Basidiomycetes  
(c) Phycomycetes (d) Deuteromycetes
44. The fungus that may cause disease in human beings is  
(a) *Puccinia* (b) *Aspergillus*  
(c) *Cystopus* (d) *Rhizopus*

45. Which of the following is not of fungal origin [Odisha JEE 2010]  
 (a) Calvacin (b) Citric acid  
 (c) Tetracycline (d) Ergotamine
46. Covered smut of *Sorghum* is caused by [BHU 2002]  
 (a) *Sphacelotheca cruenta*  
 (b) *Sphacelotheca sorghii*  
 (c) *Sphacelotheca reiliana*  
 (d) *Tolyposporium ehrenbergii*
47. The fungus used for the commercial production of SCP is [Kerala PMT 2009]  
 (a) *Pentadliandra brazzeana*  
 (b) *Fusarium graminearum*  
 (c) *Brassica napus*  
 (d) *Bacillus thuringiensis*  
 (e) *Phytophthora infestans*
48. Which of the following statement is true about fungi imperfecti [Odisha JEE 2008; BHU 2008]  
 (a) They do not have sexual phase  
 (b) They include species that prey only on nematodes  
 (c) They include toadstools, puffballs and stink horns  
 (d) They include *Aspergillus*, the fungus used to make soya sauce
49. Fungus used in genetic experiments is [NCERT; RPMT 1998]  
 (a) *Rhizopus* (b) *Mucor*  
 (c) *Neurospora* (d) *Claviceps*
50. The fungus which grows on dung is called [MP PMT 2010, 12]  
 (a) Humicolous (b) Lignicolous  
 (c) Coprophilous (d) Fungicolous
51. Match column I with column II and choose the right option
- | Column I              |    | Column II      |  |
|-----------------------|----|----------------|--|
| A. <i>Rhizopus</i>    | 1. | Ascomycetes    |  |
| B. <i>Penicillium</i> | 2. | Basidiomycetes |  |
| C. <i>Ustilago</i>    | 3. | Deuteromycetes |  |
| D. <i>Alternaria</i>  | 4. | Zygomycetes    |  |
- [CPMT 1995; Pb. PMT 1999; BVP 2000; RPMT 2005; Kerala PMT 2010]  
 (a) A-4, B-3, C-1, D-2 (b) A-2, B-3, C-4, D-1  
 (c) A-4, B-1, C-2, D-3 (d) A-3, B-4, C-2, D-1  
 (e) A-2, B-1, C-4, D-3
52. A coprophilous fungus is [JIPMER 2000]  
 (a) *Trichoderma* (b) *Pilobolus*  
 (c) *Fusarium* (d) *Humicola*
53. Fungal hyphae are able to penetrate the host with the help of [CBSE PMT 2001]  
 (a) Mechanical pressure (b) Softening by enzymes  
 (c) Both (a) and (b) (d) Suckers and hooks
54. Fungi differ from algae in being  
 (a) Coenocytic  
 (b) Without motile gametes  
 (c) Without unicellular forms  
 (d) Without chlorophyll and possessing chitinised wall
55. What is true [RPMT 2002]  
 (a) Toadstool is an edible fungus  
 (b) Rust fungi are homoeocious  
 (c) Parathecium is fruiting body  
 (d) In mushroom gills produce basidia
56. A combined solution of copper sulphate and calcium hydroxide which is used as a fungicide is  
 (a) Fehling solution (b) Folin's mixture  
 (c) Carminative mixture (d) Bordeaux mixture
57. Parasexuality is involved with [RPMT 2006]  
 (a) Fusion of gamete and protoplast  
 (b) Fusion of male gamete with secondary nucleus  
 (c) Fusion of protoplast  
 (d) Fusion of male and female gamete
58. The disease which occur at irregular intervals and locations are known as  
 (a) Epiphytotic diseases (b) Endemic diseases  
 (c) Sporadic disease (d) Epidemic diseases
59. Reserve food material of fungi is [BHU 1994, 2000; KCET 1998; MP PMT 2000; CBSE PMT 2000; Odisha JEE 2004, 05]  
 (a) Starch (b) Protein  
 (c) Glucose (d) Glycogen
60. The disease produced by fungus *Ustilago* are known as smuts because [CBSE PMT 1994]  
 (a) They parasitise cereals  
 (b) The affected host becomes completely black  
 (c) Their mycelium is black  
 (d) They produced sooty mass of spores
61. A type of life cycle in which plasmogamy, karyogamy, haplodization take place but not at specific place in life cycle of an organism is called as [RPMT 2002]  
 (a) Parasexuality (b) Heterozygosity  
 (c) Homozygosity (d) Asexuality
62. Deuteromycetes are known as fungi imperfecti because [AIIMS 2012; AFMC 2012]  
 (a) Their zygote undergoes meroblastic and holoblastic cleavage  
 (b) Only asexual stages are known  
 (c) They have aseptate mycelium  
 (d) They are autotrophic
63. Match the different types of spores listed under column I with the names of the organisms given under column II. Choose the answer which gives correct combination of the alphabets of the two columns
- | Column I<br>Spores | Column II<br>Organisms |
|--------------------|------------------------|
| A. Ascospores      | p. Diatoms             |
| B. Endospores      | q. <i>Agaricus</i>     |
| C. Auxospores      | r. Bacteria            |
| D. Basidiospores   | s. Yeast               |
|                    | t. <i>Nephrolepis</i>  |
- [KCET 1997]  
 (a) A = s, B = r, C = p, D = q  
 (b) A = s, B = p, C = r, D = q  
 (c) A = s, B = p, C = t, D = q  
 (d) A = s, B = t, C = p, D = q

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64. Which of the following is the characteristic feature of ascomycetes [MHCET 2000]  
 (a) Hyphae (b) Spores  
 (c) Zoospores (d) Ascospores
65. Phycomycetes is a class in kingdom [DPMT 2006]  
 (a) Protista (b) Fungi  
 (c) Plantae (d) Animalia
66. Fungal flagellum originates from [Odisha JEE 2005]  
 (a) Dictyosome (b) Kinetosome  
 (c) Glyoxysomes (d) Oxyosomes
67. Parasexuality was 1<sup>st</sup> discovered in [DPMT 2003; BVP 2004]  
 (a) Bacteria (b) Virus  
 (c) Fungi (d) None of these
68. Phytoalexins are secreted by plants in response to fungal reaction. These compounds are generally [DPMT 2003; BVP 2004]  
 (a) Proteins  
 (b) Glycoproteins  
 (c) Phenolic compounds  
 (d) Lipids
69. The chemical produced by the host plant to protect themselves against fungal infection is [MHCET 2002; Pb. PMT 2004]  
 (a) Toxin (b) Phytoalexin  
 (c) Phytotoxin (d) Hormone
70. Clamp connection is found in [Odisha JEE 2004; BHU 2006; MP PMT 2009]  
 (a) Basidiomycetes  
 (b) Ascomycetes  
 (c) Saccharomycetes  
 (d) Haplomycetes
71. Black rust of wheat is caused by [MHCET 2000; BVP 2004; BHU 2008; CBSE PMT (Mains) 2010]  
 (a) *Puccinia graminis* (b) *Ustilago*  
 (c) *Pythium* (d) None of these
72. Which of the following fungi is found useful in the biological control of plant disease [CPMT 2004]  
 (a) *Penicillium notatum*  
 (b) *Phytophthora parasitica*  
 (c) *Mucor mucida*  
 (d) *Trichoderma viridae*
73. Ergot fungus produces [MHCET 2004]  
 (a) Charas (b) LSD  
 (c) Marijuana (d) Ganja
74. Chloromycetin is obtained from [MHCET 2004]  
 (a) *Saccharomyces cerevisiae*  
 (b) *Streptomyces venezualae*  
 (c) *Streptomyces griseus*  
 (d) *Streptomyces erythraeus*

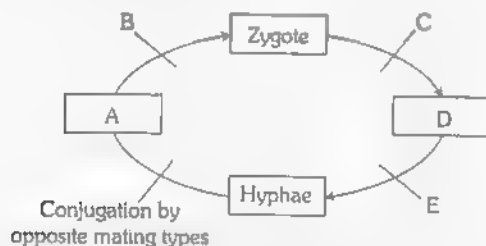
75. Which of the following correctly represents the type of life cycle patterns from the options given [Kerala PMT 2008]



- (a) 1. Diplontic 2. Haplodiplontic 3. Haplontic  
 (b) 1. Haplodiplontic 2. Haplontic 3. Diplontic  
 (c) 1. Haplontic 2. Diplontic 3. Haplodiplontic  
 (d) 1. Diplontic 2. Haplontic 3. Haplodiplontic  
 (e) 1. Haplontic 2. Haplodiplontic 3. Diplontic
76. Which of the following is an edible 'Fungi' [BHU 2005; CPMT 2009]  
 (a) *Mucor* (b) *Penicillium*  
 (c) *Agaricus* (d) *Rhizopus*
77. Saprophytic and parasitic modes of nutrition are found in [CPMT 2001, 05]  
 (a) Bacteria (b) Viruses  
 (c) Fungi (d) Both (a) and (c)
78. *Claviceps purpurea* grows as parasite [CPMT 2005]  
 (a) In human gut (b) In sugar cane roots  
 (c) On pine needles (d) On fruits of grasses
79. In addition to absence of chlorophyll what is the other difference between fungi and higher plants [DPMT 2006]  
 (a) Type of nutrition and composition of cell wall  
 (b) Cell type  
 (c) Nucleus  
 (d) Reproduction
80. Which one of the following fungi contains hallucinogens [CBSE PMT 2014]  
 (a) *Neurospora* sp. (b) *Ustilago* sp.  
 (c) *Morchella esculenta* (d) *Amanita muscaria*
81. Bakanae disease was due to [Wardha 2005]  
 (a) Fungi toxin  
 (b) Growth hormones released by fungal infection  
 (c) Inadequate nutrients  
 (d) Change in photoperiods

## Mucor and Rhizopus

82. The disease root-knot of brinjal is caused by [Kerala PMT 2006]  
 (a) *Fusarium udum* (b) *Phytophthora infestans*  
 (c) *Meloidogyne incognita* (d) *Pseudomonas rubilianeans*  
 (e) *Xanthomonas citri*
83. Select the false statement [Kerala PMT 2006]  
 (a) Scientists who study and contribute to the classification of organisms are known as systematists  
 (b) Carolus Linnaeus developed the first scientific system of naming species  
 (c) A five Kingdom arrangement of organisms was introduced by R. H. Whittaker  
 (d) Genus is a group of species which are related and have less characters in common as compared to species  
 (e) Phycomycetes are called club fungi because of a club shaped end of mycelium known as basidium
84. Red rot of sugarcane and white rust of radish are respectively caused by [Odisha JEE 2005, 11; Kerala PMT 2006]  
 (a) *Albugo candida* and *Cercospora*  
 (b) *Colletotrichum* and *Fusarium*  
 (c) *Pythium* and *Phytophthora*  
 (d) *Albugo candida* and *Puccinia graminis*  
 (e) *Colletotrichum* and *Albugo candida*
85. Identify from the following examples, a fungus which is of medicinal importance [KCET 2006]  
 (a) *Agaricus* (b) *Saccharomyces*  
 (c) *Penicillium* (d) *Cercospora*
86. Which one of the following is true for fungi [NEET (Karnataka) 2013]  
 (a) They lack a rigid cell wall  
 (b) They are heterotrophs  
 (c) They lack nuclear membrane  
 (d) They are phagotrophs
87. The given below figure shows a generalized life cycle of a fungus. The suitable terms for A, B, C, D and E are [NCERT]



	A	B	C	D	E
(a)	Meiosis	Mitosis	Spore	Fertilization	Dikaryotic phase
(b)	Dikaryotic phase	Fertilization	Meiosis	Spore	Mitosis
(c)	Fertilization	Meiosis	Mitosis	Dikaryotic phase	Amitosis
(d)	Mycelium	Mitosis	Meiosis	Fertilization	Spore

88. Which one of the following is wrong for fungi [NEET (Phase-II) 2016]  
 (a) They are both unicellular and multicellular  
 (b) They are eukaryotic  
 (c) All fungi possess a purely cellulosic cell wall  
 (d) They are heterotrophic

1. The pathogen *Microsporum* responsible for ringworm disease in humans belongs to the same Kingdom of organisms as that of [CBSE PMT (Mains) 2011]  
 (a) *Rhizopus*, a mould (b) *Ascaris*, a round worm  
 (c) *Taenia*, a tapeworm (d) *Wuchereria*, a filarial worm
2. Coenogametes are formed in [CPMT 1999]  
 (a) *Albugo* (b) *Saccharomyces*  
 (c) *Rhizopus* (d) *Alternaria*
3. Arrange the following in correct sequence with reference to sexual reproduction in *Rhizopus*  
 (I) Formation of germ tube  
 (II) Formation of zygothecia  
 (III) Formation of warty wall layer of zygospore  
 (IV) Secretion of trisporic acid  
 The correct sequence is [EAMCET 2009]  
 (a) IV, III, II, I (b) IV, II, III, I  
 (c) II, I, IV, III (d) I, III, II, IV
4. Which of the following environmental conditions are essential for optimum growth of *Mucor* on a piece of bread  
 A. Temperature of about 25°C  
 B. Temperature of about 5°C  
 C. Relative humidity of about 5%  
 D. Relative humidity of about 95%  
 E. A shady place  
 F. A brightly illuminated place  
 Choose the answer from the following options [CBSE PMT 2006]  
 (a) B, D and E only (b) B, C and F only  
 (c) A, C and E only (d) A, D and E only
5. In *Mucor*, asexual reproduction takes place by  
 (a) Motile zoospores (b) Spores  
 (c) Zoogametes (d) Zygospores
6. Which one of the following life cycle is associated with *Mucor*  
 (a) Haplontic (b) Diplontic  
 (c) Isomorphic (d) Heteromorphic
7. Zygospores are formed in [MP PMT 1995; AFMC 2002; Odisha JEE 2005]  
 (a) *Puccinia* (b) *Penicillium*  
 (c) *Alternaria* (d) *Mucor* / *Rhizopus*
8. Which one is wrong statement [AIPMT 2015]  
 (a) *Mucor* has biflagellate zoospores  
 (b) Haploid endospore is typical feature of gymnosperms  
 (c) Brown algae have chlorophyll a and c and fucoxanthin  
 (d) Archegonia are found in bryophyta, pteridophyta and gymnosperms
9. Columella is a specialized structure found in the sporangium of [CBSE PMT 1999; BHU 1999; CPMT 2004; Bihar CECE 2006]  
 (a) *Ulothrix* (b) *Rhizopus*  
 (c) *Spirogyra* (d) None of these



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10. Which of the following induces sexual reproduction in *Mucor/Rhizopus*
    - (a) Indole acetic acid
    - (b) Trisporic acid
    - (c) Gibberellic acid
    - (d) Citric acid
  11. In *Rhizopus*, hyphae are [RPMT 2002]
    - (a) Branched, septate and uninucleate
    - (b) Branched, aseptate and multinucleate
    - (c) Unbranched, aseptate and multinucleate
    - (d) Unbranched, septate and coenocytic
  12. Multinucleated filament of *Rhizopus* is [RPMT 1997; BCECE 2005]
    - (a) Coenocytic
    - (b) Conidia
    - (c) Heterothallus
    - (d) Homothallus
  13. *Mucor* shows [MP PMT 2002]
    - (a) Isogamy
    - (b) Anisogamy
    - (c) Oogamy
    - (d) None of the above
  14. Sporangiospores of *Mucor* are [MP PMT 2002]
    - (a) Haploid
    - (b) Diploid
    - (c) Triploid
    - (d) Polyploid
  15. For *Mucor* zygospore is [DPMT 2007]
    - (a) Thick walled resting spore
    - (b) Haploid in structure
    - (c) Result of asexual reproduction
    - (d) Germinates to form zoospores
  16. The zygospore in *Rhizopus* develops into [J & K CET 2002]
    - (a) Zygospore
    - (b) Promycelium
    - (c) Progametangium
    - (d) Gametangium
  17. The reduction division in the life cycle of *Rhizopus* occurs
    - (a) At the time of germination of zygospores
    - (b) During the formation of germ sporangium
    - (c) During asexual reproduction
    - (d) During the formation of gametangium
  18. Which of the following plant and its mode of nutrition is not correctly matched [AIEEE Pharmacy 2003]
    - (a) *Cuscuta* – Stem parasite
    - (b) *Mucor* – Autotroph
    - (c) *Orobancha* – Root parasite
    - (d) *Dracopis* – Insectivorous
  19. Which one of the following fungus shows heterothallism [BHU 1999; MHCET 2001]
    - (a) *Erysiphe*
    - (b) *Peziza*
    - (c) *Rhizopus*
    - (d) *Peronospora*
  20. Common bread mould is [MP PMT 1996, 2010, 12; CBSE PMT 2001]
    - (a) *Rhizopus oryzae*
    - (b) *Rhizobium* species
    - (c) *Rhizopus nedosus*
    - (d) *Rhizopus stolonifer*
  21. In *Rhizopus* if conjugation fails, gametangia behave as zygospore. It is called as [AIIMS 2000]
    - (a) Conidia
    - (b) Parthenospore
    - (c) Gametangia
    - (d) Sporangiospore
  22. Yeast like budding of oidia in *Mucor/Rhizopus* is called [MP PMT 2001]
    - (a) Palmella
    - (b) Chytridia
    - (c) Torula
    - (d) Gongrosira
  23. Mode of nutrition in *Rhizopus* is [AFMC 1993]
    - (a) Parasitic
    - (b) Symbiotic
    - (c) Saprophytic
    - (d) Autotrophic
  24. Mycelium of *Mucor/Rhizopus* is [MP PMT 2000]
    - (a) Aseptate and unicellular
    - (b) Septate and unicellular
    - (c) Septate and multicellular
    - (d) Coenocytic
  25. Food stored in *Rhizopus/Mucor* as [CBSE PMT 1992; RPMT 1996, 2000]
    - (a) Protein and steriods
    - (b) Sugar and oil
    - (c) Protein and starch
    - (d) Glycogen and oil
  26. The wall of *Rhizopus* hypha is composed of [MP PMT 2001; PET (Pharmacy) 2013]
    - (a) Cellulose
    - (b) Chitin
    - (c) Pectin
    - (d) Hemicellulose
- ### Yeast and Albugo
1. Botanical name of species which cause white rust of cruciferae [RPMT 2002, 06]
    - (a) *Peronospora parasitica*
    - (b) *Puccinia graminis*
    - (c) *Pythium debaryanum*
    - (d) *Albugo candida*
  2. Fungus without any mycelium is [BHU 2000; MHCET 2000]
    - (a) *Albugo*
    - (b) *Agaricus*
    - (c) *Puccinia*
    - (d) *Saccharomyces*
  3. Branched, aseptate, coenocytic mycelium present in [RPMT 2002]
    - (a) *Aspergillus*
    - (b) *Albugo*
    - (c) *Penicillium*
    - (d) *Erysiphe*
  4. Yeast produces an enzyme complex that is responsible for fermentation. The enzyme complex is [MP PMT 2013]
    - (a) Aldolase
    - (b) Dehydrogenase
    - (c) Invertase
    - (d) Zymase
  5. Which statement is incorrect for *Albugo* [RPMT 1995, 96]
    - (a) Biflagellated male gametes
    - (b) Non-flagellated female gametes
    - (c) Biflagellated zoospores
    - (d) All of the above
  6. Which of the following is an unicellular sac-fungus [Kerala PMT 2011]
    - (a) *Claviceps*
    - (b) *Saccharomyces*
    - (c) *Penicillium*
    - (d) *Neurospora*
    - (e) *Aspergillus*
  7. Yeast is not included in protozoans but in fungi because [Manipal 2005]
    - (a) It has no chlorophyll
    - (b) Some fungal hyphae grow in such a way that they give the appearance of pseudomycelium
    - (c) It has eukaryotic organisation
    - (d) Cell wall is made up of cellulose and reserve food material as starch

8. Mycelium in *Albugo* is [RPMT 1995]  
(a) Intracellular (b) Intercellular  
(c) Surface of host (d) Surface of flower
9. In *Albugo* the food reserve is mostly [RPMT 1995]  
(a) Glycogen (b) Volutin granules  
(c) Protein granules (d) Fat
10. Yeast is divided under the class [CPMT 2003]  
(a) Basidiomycetes (b) Deuteromycetes  
(c) Ascomycetes (d) Zygomycetes
11. Which organism is used to obtain the single cell protein [AMU (Med.) 2005]  
(a) Bacteria (b) Yeast  
(c) Filamentous Fungi (d) All of the above
12. In manufacture of bread, it becomes porous due to release of  $CO_2$  by the action of [CBSE PMT 2002]  
(a) Virus (b) Yeast  
(c) Bacteria (d) Protozoans
13. Pseudomycelium is formed in [BHU 2002]  
(a) Yeast (b) *Rhizophora*  
(c) *Aspergillus* (d) *Synchytrium*
6. Mycorrhiza works as [CPMT 1998; BHU 2002]  
(a) Modified root  
(b) An organism for vegetative propagation  
(c) A root hair in adverse condition  
(d) Mechanical tissue for support
7. Which statements is wrong about lichens [CBSE PMT 1996]  
(a) Some species are eaten by reindeers  
(b) Lichens are indicators of pollution  
(c) They grow rapidly about 2cm per day  
(d) They have symbiotic relationship between alga and fungus
8. Fungal partner of a lichen is commonly [BHU 1996]  
(a) Ascomycetes (b) Basidiomycetes  
(c) Phycomycetes (d) Deuteromycetes
9. Mycorrhizal association occurs in *Pinus*, *Ficus* and [HPMT 2000]  
(a) *Utricularia* (b) Legumes  
(c) *Eucalyptus* (d) *Azadirachta*
10. Fungus/Lichens which grow on wood is [AFMC 2004]  
(a) Terricolous (b) Saxicolous  
(c) Lignicolous (d) Corticolous
11. Short twisted strands of hyphae which serves as anchors for lichens [Odisha JEE 2008]  
(a) Mycelium (b) Rhizines  
(c) Roots (d) Rhizoids
12. A teacher was explaining about a constant physical contact involving almost equal physiological interdependence in two different thaloid forms. He was trying to explain one of the following [EAMCET 2009]  
(a) Mycorrhizal association  
(b) Establishment of heterothallism  
(c) Operation of heterothallism  
(d) Advent of lichen formation
13. In majority of lichens, there is association of [CBSE PMT 2001]  
(a) Green algae and ascomycetes  
(b) Green algae and basidiomycetes  
(c) Blue green algae and ascomycetes  
(d) Blue green algae and basidiomycetes
14. Lichen is [BHU 2008]  
(a) Saprophytic (b) Parasitic  
(c) Holozoic (d) Autotrophic
15. Lichens grow at a very slow rate (1 mm per year). In how many years a lichen matures  
(a) 1 – 4 years (b) 4 – 8 years  
(c) 100 years (d) 20 – 25 years
16. There exists a close association between the algae and the fungus within a lichen. The fungus [CBSE PMT 2005]  
(a) Fixes the atmospheric nitrogen for the alga  
(b) Provides protection, anchorage and absorption for the alga  
(c) Provides food for the alga  
(d) Releases oxygen for the alga

### Lichen and Mycorrhiza

1. 'Mycorrhizae' are useful for plants mainly due to their following attribute [CPMT 1993, 94, 2004; BHU 1994, 2001; Pb. PMT 1999; DPMT 2003, 06; RPMT 2006]  
(a) Fixing atmospheric nitrogen  
(b) Enhanced absorption of nutrients from soil  
(c) Killing insects and pathogens  
(d) Providing resistance against abiotic stresses
2. In lichens, sexual reproduction belongs to [BHU 1994]  
(a) Fungal partner only  
(b) Algal partner only  
(c) Fungal and algal partners (both)  
(d) Either fungal partner or algal partner (not both)
3. Which one of the following pairs is correctly matched [AIIMS 2003, 07]  
(a) Rhizobium – Parasite in the roots of leguminous plants  
(b) Mycorrhizae – Mineral uptake from soil  
(c) Yeast – Production of biogas  
(d) Myxomycetes – The disease ring worm
4. Mycorrhiza is a [CPMT 1994]  
(a) Long thin root  
(b) Association of root and fungus  
(c) Root like underground stem  
(d) Parasitic root
5. The symbiotic association of fungi and algae is called [CPMT 1996, 98; AFMC 1998; KCET 2000; Chd. CET 2000; CBSE PMT 2001; J & K CET 2012]  
(a) Lichen (b) Mycorrhiza  
(c) Both (a) and (b) (d) Mycoplasma

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17. An example of endomycorrhiza is [CBSE PMT (Mains) 2010]
  - (a) *Nostoc* (b) *Glomus*
  - (c) *Agaricus* (d) *Rhizobium*
18. Lichens are ecologically important as they
  - (a) Purify air
  - (b) Are pioneers of barren rocks
  - (c) Are symbionts of algae and fungi
  - (d) Are associated with mycorrhizal roots
19. Reindeer moss is [AFMC 1996; RPMT 1999]
  - (a) *Sphagnum* (b) *Marchantia*
  - (c) *Cladonia rangiferina* (d) None of these
20. Association of fungus with roots of tracheophytes is [BVP 2002]
  - (a) Mycorrhiza (b) Commensalism
  - (c) Helotism (d) Amensalism
21. Which one of the following helps in absorption of phosphorus from soil by plants [CBSE PMT (Pre.) 2011]
 

Or

Which one of the following microbes forms symbiotic association with plants and helps them in their nutrition [CBSE PMT (Pre.) 2012]

  - (a) *Azotobacter* (b) *Glomus*
  - (c) *Aspergillus* (d) *Trichoderma*
22. Mycorrhiza is a relationship of roots of *Pinus* and [BVP 2001; MHCET 2001]
  - (a) Fungus (b) Alga
  - (c) Bacteria (d) Ants
23. Which of the following symbiotic association is not useful as biofertilizer [MHCET 2002]
  - (a) *Rhizobium* and leguminous roots
  - (b) Algae and fungi
  - (c) *Azolla* and *Anabaena*
  - (d) Roots of higher plants and fungi
24. Mycorrhiza exhibits the phenomenon of [CBSE PMT 1994; BVP 2002]
  - (a) Antagonism (b) Endemism
  - (c) Parasitism (d) Symbiosis
25. Helotism is a term used for the symbiosis of [MHCET 2003]
  - (a) Algae and bacteria (b) Algae and bryophytes
  - (c) Algae and pteridophytes (d) Algae and fungi
26. Litmus is obtained from [Odisha JEE 2004]
  - (a) Lichen (b) Algae
  - (c) Fungi (d) Protozoa
27. Lichens are well known combination of an alga and a fungus where fungus has [CBSE PMT 2004; Pb. PMT 2004; CPMT 2005]
  - (a) A parasitic relationship with the alga
  - (b) A symbiotic relationship with the alga
  - (c) A saprophytic relationship with the alga
  - (d) An epiphytic relationship with the alga
28. *Cladonia rangiferina* is a/an [BHU 2004]
  - (a) Algae (b) Lichen
  - (c) Fungus (d) Angiosperm

## NCERT

### Exemplar Questions

1. Naked cytoplasm, multinucleated and saprophytic are the characteristics of [NCERT]
  - (a) Monera (b) Protista
  - (c) Fungi (d) Slime molds
2. An association between roots of higher plants and fungi is called [NCERT]
  - (a) Lichen (b) Fern
  - (c) Mycorrhiza (d) BGA
3. A dikaryon is formed when [NCERT]
  - (a) Meiosis is arrested
  - (b) The two haploid cells do not fuse immediately
  - (c) Cytoplasm does not fuse
  - (d) None of the above
4. Mycobiont and Phycobiont are found in [NCERT]
  - (a) Mycorrhiza (b) Root
  - (c) Lichens (d) BGA
5. With respect to fungal sexual cycle, choose the correct sequence of events [NCERT]
  - (a) Karyogamy, Plasmogamy and Meiosis
  - (b) Meiosis, Plasmogamy and Karyogamy
  - (c) Plasmogamy, Karyogamy and Meiosis
  - (d) Meiosis, Karyogamy and Plasmogamy
6. Members of phycomycetes are found in
  - i. Aquatic habitats
  - ii. On decaying wood
  - iii. Moist and damp places
  - iv. As obligate parasites on plants

Choose from the following options [NCERT]

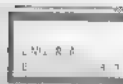
  - (a) None of the above (b) i and iv
  - (c) ii and iii (d) All of the above

## Critical Thinking

### Objective Questions

1. Which of the following is not matched correctly [Kerala PMT 2011]
 

(a) <i>Anabaena</i>	-	Cyanobacteria
(b) <i>Amoeba</i>	-	Protozoa
(c) <i>Gonyaulax</i>	-	Dinoflagellates
(d) <i>Thermoacidophils</i>	-	Archaeobacteria
(e) <i>Albugo</i>	-	Chrysophytes
2. 'Torula condition' occurs in [MP PMT 2001]
  - (a) *Rhizopus* (b) *Ulothrix*
  - (c) *Spirogyra* (d) *Riccia*



3. Match the following and choose the correct combination from the options given

Column I (Group)	Column II (Example)
A. Eubacteria	1. <i>Trichoderma</i>
B. Dinoflagellates	2. <i>Albugo</i>
C. Phycomycetes	3. <i>Gonyaulax</i>
D. Deuteromycetes	4. <i>Anabaena</i>

[J & K CET 2012; Kerala PMT 2012]

- (a) A-1; B-2; C-3; D-4 (b) A-2; B-3; C-4; D-1  
(c) A-4; B-3; C-2; D-1 (d) A-3; B-4; C-1; D-2  
(e) A-4; B-3; C-1; D-2
4. A fungus which requires only one single host for completion of its life cycle is called [Chd. CET 2000]  
(a) Heteroecious (b) Autoecious  
(c) Heterothallism (d) Heterosporous
5. Fungi can be stained by [AFMC 1993; BVP 2000]  
(a) Safranin (b) Iodine  
(c) Lactophenol (d) Cotton blue
6. Asci are formed in  
(a) *Ascobolus* (b) *Saccharomyces*  
(c) *Penicillium* (d) All the above
7. No need of water for fertilization in [RPMT 1995]  
(a) *Ulothrix* (b) *Albugo*  
(c) Bryophyta (d) Pteridophyta
8. Ray fungi are [BHU 1995]  
(a) Ascomycetes (b) Basidiomycetes  
(c) Actinomycetes (d) Phycomycetes
9. Which one of the following group of fungi is sometimes known as "fungal waste basket"  
(a) Phycomycetes (b) Ascomycetes  
(c) Basidiomycetes (d) Deuteromycetes
10. In *Puccinia*, infection from barberry leaf to wheat plant is caused by [JIPMER 2001]  
(a) Pycnospores (b) Aecidiospores  
(c) Uredospores (d) Teleutospores
11. Powdery mildews of crops are caused by [AIIMS 2001; MHCET 2003; Odisha JEE 2012]  
(a) Bacteria (b) Ascomycetes (*Erysiphe*)  
(c) Phycomycetes (d) Basidiomycetes
12. Which of the following fungal disease spreads by seed and flowers [CBSE PMT 2002]  
(a) Corn stunt (b) Covered smut  
(c) Potato root (d) Loose smut of wheat
13. The edible part of mushroom is [CPMT 2003; BHU 2006; WB JEE 2011]  
(a) Basidiocarp (b) Tertiary mycelium  
(c) Primary mycelium (d) Secondary mycelium
14. Which one single organism or the pair of organisms is correctly assigned to its or their named taxonomic group [CBSE PMT (Pre.) 2012]  
(a) *Paramecium* and *Plasmodium* belong to the same kingdom as that of *Penicillium*  
(b) Lichen is a composite organism formed from the symbiotic association of an algae and a protozoan  
(c) Yeast used in making bread and beer is a fungus  
(d) *Nostoc* and *Anabaena* are examples of protista

15. Which option shows incorrectly matched group

[GUJCET 2014]

- (a) Pseudopodiospore – *Plasmodium* – Sporulation  
(b) Gemmules – *Spongilla* – Budding  
(c) Zoospores – *Aspergillus* – Sporulation  
(d) Conidia – *Penicillium* – Asexual reproduction

16. Catabolism Considering mode of asexual reproduction, match the Column I with II and select the correct option

I		II	
A.	Yeast	I.	Fragmentation
B.	<i>Penicillium</i>	II.	Zoospores
C.	Filamentous algae	III.	Budding
D.	<i>Chlamydomonas</i>	IV.	Conidia

[MHCET 2015]

- (a) A-III, B-IV, C-I, D-II (b) A-II, B-III, C-I, D-IV  
(c) A-IV, B-III, C-II, D-I (d) A-III, B-II, C-I, D-IV

## R Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

- (a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion  
(b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion  
(c) If the assertion is true but the reason is false  
(d) If both the assertion and reason are false  
(e) If the assertion is false but reason is true

1. Assertion : Symbiosis is furnished by mycorrhiza.  
Reason : In mycorrhiza, symbiosis is established between fungus and alga. [AIIMS 1995]
2. Assertion : Fruticose are well branched leafy lichens.  
Reason : These lichens are upright and have pendulous organisation and are attached to substratum by a discoid structure. [AIIMS 1996]
3. Assertion : Aflatoxins are produced by *Aspergillus flavus*.  
Reason : These toxins are useful to mankind. [AIIMS 2000, 13]
4. Assertion : Deuteromycetes lack sexual reproduction.  
Reason : Fungi show three type of reproduction asexual, sexual and vegetative.
5. Assertion : "Fungi imperfecti" does not show alternation of generation.  
Reason : The diploid phase is present in only zygote.
6. Assertion : *Rhizopus* and *Mucor* are used in liquor industry.  
Reason : They cause fermentation.
7. Assertion : *Morels* and *Truffles* are edible fungi.  
Reason : Ascocarps are edible.
8. Assertion : *Saccharomyces ellipsoidens* is Baker's yeast and *Saccharomyces cerevisiae* is Wine yeast.  
Reason : Yeast is used to make dry ice

## 98 Fungi (Multicellular decomposers)

9. Assertion : Yeast are the best source of vitamin B complex.  
Reason : *Ashbya gossypii* is a filamentous yeast.
10. Assertion : *Claviceps* produces lysergic acid.  
Reason : It is carcinogenic.
11. Assertion : Mushrooms are called fairy rings.  
Reason : Mushroom consists of two parts-stipe and pileus.
12. Assertion : Basidiocarps are called fungus flowers.  
Reason : The beautiful fruit bodies are found in Basidiomycotina.
13. Assertion : Fruticose lichens have the simplest thallus.  
Reason : The thallus is attached only at the base by a flattened disc.
14. Assertion : The fungi are widespread in distribution and they even live on inside other plants and animals.  
Reason : Fungi are able to grow anywhere on land, water or on other organisms because they have a variety of pigments, including chlorophyll, carotenoids, fucoxanthin and phycoerythrin. [AIIMS 2005]

## Answers

## Fungi (General)

1	a	2	c	3	d	4	b	5	a
6	a	7	a	8	b	9	a	10	a
11	a	12	a	13	d	14	c	15	d
16	d	17	d	18	b	19	c	20	a
21	a	22	a	23	a	24	c	25	b
26	b	27	c	28	b	29	d	30	c
31	b	32	c	33	c	34	c	35	b
36	d	37	a	38	a	39	b	40	c
41	a	42	d	43	c	44	b	45	c
46	b	47	b	48	a	49	c	50	c
51	c	52	b	53	c	54	d	55	d
56	d	57	c	58	c	59	d	60	d
61	a	62	b	63	a	64	d	65	b
66	b	67	c	68	c	69	b	70	a
71	a	72	b	73	b	74	b	75	d
76	c	77	d	78	d	79	a	80	d
81	b	82	c	83	e	84	e	85	c
86	b	87	b	88	c				

## Mucor and Rhizopus

1	a	2	c	3	b	4	d	5	b
6	a	7	d	8	a	9	b	10	b
11	b	12	a	13	a	14	a	15	a
16	b	17	a	18	b	19	c	20	d
21	b	22	c	23	c	24	d	25	d
26	b								

## Yeast and Albugo

1	d	2	d	3	b	4	d	5	a
6	b	7	b	8	b	9	a	10	c
11	c	12	b	13	a				

## Lichen and Mycorrhiza

1	b	2	a	3	b	4	b	5	a
6	c	7	c	8	a	9	c	10	c
11	b	12	d	13	c	14	d	15	b
16	b	17	b	18	b	19	c	20	a
21	b	22	a	23	b	24	d	25	d
26	a	27	b	28	b				

## NCERT Exemplar Questions

1	d	2	c	3	b	4	c	5	c
6	d								

## Critical Thinking Questions

1	e	2	a	3	c	4	b	5	d
6	d	7	b	8	c	9	d	10	b
11	b	12	d	13	a	14	c	15	c
16	a								

## Assertion and Reason

1	c	2	a	3	c	4	b	5	c
6	a	7	a	8	b	9	b	10	c
11	b	12	a	13	a	14	c		

## Answers and Solutions

## Fungi (General)

- (a) The term fungus was used by Gaspard Bauhin (1560-1624).
- (c) Father of modern mycology and plant pathology is H.A. De Bary (a German botanist)

8. (b) Due to the presence of mentioned characters in question, this group is also called fungi imperfecti.
9. (c) Conidia are non-motile spores produced exogenously by constrictions at the tip of special hyphae called conidiophores.
11. (a) Heterotrophs : Fungi (lack chlorophyll) obtain their nutrition from the extracellular digestion and absorption of the digested material such mode of nutrition is called heterotrophic and the organism called heterotrophs.
13. (d) T.S. Sadasivan work on physiology of infection by *Fusarium*. Other famous Indian mycologists are K.C. Mehta, B.B. Mundkar and C.V. Subramaniam.
14. (c) Koch postulates are applicable to bacteria and fungi as pathogen.
16. (d) Brown leaf spot of rice is a seed born disease, which is caused by *Helminthosporium oryzae*.
18. (b) Morel and truffles are edible and members of Ascomycetes in fungi.
20. (a) Mushroom is a basidiomycetes fungus, which is grow on dead and decay matter.
24. (c) Covered smut of barley is caused by *Ustilago hordei*.
25. (b) Late blight of potato is a seed born disease which is caused by *Phytophthora infestans*. The disease is characterised by brownish to blackish dead areas on the tip and margin of the leaflet leading to blighting of the whole leaf. So the tuber formation is reduced.
27. (c) All fungi are heterotrophs in their nutrition. Some are depends upon organic matter known as saprophytes.
28. (b) Modes of nutrition is three types .  
(a) Saprophytic (b) Parasitic (c) Symbiotic (Mycorrhiza).
29. (d) The members of division basidiomycota (class basidiomycetes) are commonly called club fungi because the basidia are club shaped.
30. (c) Aflatoxins are produced by fungi (*Aspergillus flavus*).
32. (c) The septum of higher fungi is more complex dolipore (Latin dolium = a large jar). It is a barrel shaped pore with open end.
33. (c) *Aspergillus flavus* grows on stored cereal grains, groundnut and areca nut produce a carcinogenic toxin called aflatoxin.
35. (b) The mycelium of *Aspergillus* consist of branch septate hyphae. Cells of hyphae are multinucleate.
37. (a) In gametangial copulation two gametangia come in contact and fuse completely to form a zygote or zygospore. It is found in members of zygomycetes, e.g., *Rhizopus* and *Mucor*.
39. (b) It is the first stage of sexual reproduction in which the cytoplasm of two sex cells fuse with each other. The nuclei of sex cells come close to each other but do not fuse. Thus the resulting cell becomes binucleate or dikaryon.
43. (c) Many scientist (Sachs, 1874; Bessey, 1950) believe that fungi, particularly class Phycomycetes, have evolved from siphonaceous green algae. Both the group have some common features such as presence of coenocytic thalli, flagellated zoospores, streaming movement and mode of sexual reproduction. Therefore Phycomycetes is called algal fungi.
44. (b) The fungus *Aspergillus* produces aflatoxins which are carcinogenic and may cause cancer in human beings.
49. (c) Many species of *Neurospora* have been used as convenient organisms for genetical (one gene – one enzyme theory by Beadle and Tatum) and biochemical studies. *Neurospora* is also known as *Drosophila* of plant kingdom.
52. (b) Coprophilous fungi grow on dung, e.g., *Pilobolus crystallinus*.
56. (d) Bordeaux mixture was the first fungicide to be discovered. It is discovered by proff. Millardet of Bordeaux university. This mixture consists of copper sulphate, lime and water (calcium hydroxide). This mixture is called holy water of plant pathology and effective against white rust, mildews and blights.
57. (c) Parasexuality is related with protoplast fusion and found in fungus.
58. (c) Sporadic disease occurs occasionally at irregular intervals in fewer area and only few plants in a locality are infected, e.g., Blotch disease of cucumbers, angular leaf spot of cotton.
64. (d) In ascomycetes, diploid nucleus divided by meiosis and then by mitosis to form 8 (sometimes only 4) haploid ascospores. These sexually produced ascospores remain inside the sac like structure called ascus.
67. (c) Parasexuality was first discovered by Pontecorvo and Roper (1952) in a fungus *Aspergillus nidulans*. Parasexuality help in recombination without meiosis and fertilization.
68. (c) Phytoalexins are phenolic compound produce in the host cell for defense in response to fungal infection (Muller and Borger, 1940). These chemicals inhibit growth of the parasite.
70. (a) In many members of basidiomycetes cells division accompanied by clamp connection. These are bridge (hook) like connection. They function as bypass hyphae through which nuclei migrate to make all of mycelium dikaryotic.
71. (a) *Puccinia graminis tritici* causes black rust of wheat.
73. (b) LSD (Lysergic acid diethylamide) is the most powerful hallucinogen. It is a crystalline amidated alkaloid obtained from ergot. i.e., an extract got from a fungus *Claviceps purpurea*, that is parasite on rye.

## 100 Fungi (Multicellular decomposers)

74. (b) Chloromycetin is an antibiotic which obtained from *Streptomyces venezuelae*.
76. (c) The fructifications of certain fungi are used as nutritious and delicious food e.g., *Agaricus bisporus* and *A. campestris* (mushrooms).
77. (d) Both are heterotrophic in their mode of nutrition, so they are saprophytic or parasitic.
78. (d) *Claviceps purpurea* (ergot fungus) causes ergot of cereals especially of rye (*secale cereale*).
79. (a) Fungi lack chlorophyll, therefore, heterotrophic in nature. Their cell wall is formed of chitin (fungus cellulose). The cells in higher plants and fungi is eukaryotic i.e., possess a well developed nucleus.
80. (d) *Amanita muscaria* is noted for its hallucinogenic properties, with its main psychoactive constituent being the compound muscimol.
81. (b) Bakane disease of rice is caused by *Fusarium moniliforme*. The perfect stage of this fungus is *Gibberella fujikuroi* (ascomycete). *Gibberella* produces the plant hormone gibberellin.
88. (c) Cell wall of fungi is made up of chitin and polysaccharides.
14. (a) Sporangiospores are produced in large number inside the sporangia of *Mucor*, which are borne over special hyphae known as sporangiophore. These spore are produced during asexual reproduction.
16. (b) Sexual reproduction results in the formation of diploid zygospore. The zygospore absorbs water and swell. The exospore ruptures and the endospore protrudes out in the form of a hypha, called promycelium.
19. (c) When in *Rhizopus* (+) and (-) strains are found separately (physiologically), then this condition is called as heterothallism.
20. (d) *Rhizopus* (pin mould or black mould) grows on bread and hence also called bread mould.
22. (c) In liquid medium, rich in sugar and acidic pH, the hyphae of *Rhizopus/Mucor* produce small rounded oidia, which multiply by budding like yeast. This budding condition is called torula stage.

### Yeast and Albugo

4. (d) The yeast cells secrete extracellular enzyme-*zymase* which converts complex sugar into simple soluble sugar.
8. (b) The mycelium is intercellular branched, aseptate and multinucleate. The mycelium produces finger like or globular haustoria which enter into the host cells to absorb the food material.
10. (c) True yeast bear asci which are not organized into ascocarps. e.g., *Schizosaccharomyces*, *Saccharomyces*, *Saccharomyces*, *Zygosaccharomyces*, *Nematospora*. Therefore, yeast are classified under ascomycetes.
12. (b) Selected strains of *Saccharomyces* are used as Baker's yeast. It is available as powder or cake. The same is added to flour during kneading. Yeast secretes amylase (change some starch to maltose), maltase (maltose to glucose) and zymase (glucose to ethyl alcohol and CO<sub>2</sub>). The dough swells up or leavens. Leavened dough is baked. Both alcohol and CO<sub>2</sub> evaporate. The bread becomes soft and porous.
13. (a) Yeast reproduces by means of budding. Sometime the bud starts forming new bud before it separates from parent cell. This may result in formation of branched and unbranched chains of bud which is called as pseudomycelium.

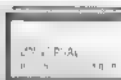
### Lichen and Mycorrhiza

2. (a) Sexual reproduction in lichen is performed only or mainly by its fungal component.
6. (c) In adverse conditions ectomycorrhiza work as root hairs to absorb water as in *Pinus*. Because gymnosperms do not have root hair.
7. (c) Lichen are slow growing and grow at the rate of 1 mm per year.

### Mucor and Rhizopus

2. (c) Each progametangium of *Rhizopus* undergoes division to form gametangium and suspensor. The two gametangia are in contact with each other. They contain multinucleate protoplasts that behave as aplanogamete or coenogamete.
5. (b) In asexual reproduction of *Mucor* three type of non-motile mitospores are produced. i.e., sporangiospores, chlamydospores and oidia.
7. (d) Fusion of coenogametes (*Rhizopus* and *Mucor*) produced a diploid resting spore called zygospore.
9. (b) The sporangium of *Rhizopus* is appear to be divide into two regions, i.e., Outer fertile sporiferous zone and a central sterile columella. The protoplast of the sporiferous zone cleave mitotically to form dark coloured multinucleate spores.
10. (b) The process is initiated by the secretion of trisporic acid which stimulates the formation of special hyphae, called zygophores, from both of the compatible mycelia (+) strain and (-) strain.
12. (a) The hyphae are aseptate and multinucleate (i.e., Coenocytic).
13. (a) Both (+) and (-) progametangium are similar in structure





13. (c) In lichens fungus partner or mycobiont (mostly ascomycete) and an algal partner called photobiont or phycobiont (mostly blue-green alga).
17. (b) *Nostoc* – BGA, *Agaricus*-Basidiomycetes, *Rhizobium*-Eubacteria
18. (b) Lichens are considered as pioneers in initiating a plant succession on rocks.
19. (c) Reindeer moss (*Cladonia rangiferina*) of the arctic region is the used as food for reindeer and cattle.
21. (b) *Glomus* is a endomycorrhiza for phosphorus absorption
24. (d) Mycorrhiza is a symbiotic association of a saprophytic fungus with the roots of higher.
25. (d) Helotism is a form of symbiosis in which one partner benefits more than the other. e.g., Fungus in lichen thallus benefits more than the alga.
26. (a) Litmus used as acid-base indicator is obtained from *Rocella montagnei* and *Lasallia pastulata*.
4. (b) Sexual reproduction is absent (as the sexual stage is absent) in the artificial group of fungi called fungi imperfecti or deuteromycetes.
5. (c) Fungi imperfecti is that group of fungi where only the imperfect stage (asexual stages) is present. The only known method of reproduction is by conidia (asexual reproduction). As sexual reproduction is absent in this group therefore diplophase is also absent.
6. (a) Both *Rhizopus* and *Mucor* species are used in alcoholic fermentation. The two produce a number of organic acids like citric acid, lactic acid and fumaric acid.
7. (a) The fructifications of some ascomycetes, i.e., ascocarps are edible, e.g., morels, truffles.
8. (b) The two common yeasts used by brewing industry are *Saccharomyces cerevisiae* (Beer or Baker's yeast) and *S. ellipsoidens* (Wine Yeast). In the baking or brewing industry CO<sub>2</sub> is the useful product. It is collected, solidified and sold as "dry ice".
9. (b) The yeasts are the best sources of vitamin B complex. Riboflavin (B<sub>6</sub>) is obtained from a filamentous yeast *Ashby gossypii*.
10. (c) A derivative of ergot known by name of lysergic acid (LSD) is used in experimental psychiatry, as it is a hallucinogen.
11. (b) The basidiocarps or mushrooms often lie in rings. Therefore, are spoken as fairy rings. Each basidiocarp consists of two parts-stipe and pileus. The stipe or stalk is fleshy. Pileus is umbrella-like cap of the mushroom.
12. (a) The fruit bodies of Basidiomycotina, called basidiocarps are most attractive and beautiful of all fungi and therefore are called fungus flowers.
13. (e) Fruticose lichens have a most complex thallus which is slender and freely branched. The branches may be cylindrical or ribbon-like and form thread-like or twig-like tufts. The thallus is attached only at the base by a flattened disc
14. (c) Fungi are considered ubiquitous i.e., they occur in a variety of habitats. Most of them are moisture loving and terrestrial and few (e.g., *Monoblepharis*) are aquatic. Fungi may be **epiphytic** (i.e., live on plants e.g., *Armillaria*), **saprophytic** (i.e., grow in dead organic matter e.g., *Mucor*), **symbiotic** (i.e., live with association with other plants e.g., lichen, mycorrhiza) and **predacious** (e.g., *Dactyldela*) and parasitic (e.g., *Erysip*) fungi are non-chlorophyllous i.e., devoid of chlorophyll hence cannot prepare their own food. They are heterotrophic and show absorptive type of nutrition.

### Critical Thinking Questions

5. (d) Fungi can be stained with cotton blue. This stain provide blue colour of chitinous cell wall
6. (d) *Ascomobolus*, *Saccharomyces* and *Penicillium* belong to ascomycetes.
7. (b) In algae (*Ulothrix*), bryophytes and pteridophytes, water is necessary for fertilization.
9. (d) Duteromycetes is also known as fungal waste basket because its lack perfect sexual stage.
11. (b) Powdery mildew diseases are characterized by the presence of fungal mycelium, conidiophore and conidia as white powdery patches on the host. Powdery mildew is caused by fungi which belongs to ascomycetes.
12. (d) Loose smut of wheat is caused by *Ustilago tritici*, which is seed borne disease
13. (a) Basidiocarp is a fruiting body of basidiomycetes. It is a edible part of mushroom.
14. (c) *Saccharomyces cerviciae* is a yeast used in making bread (Baker's yeast) and commercial production of ethanol.
15. (c) *Aspergillus* do not produce motile spore (zoospore).

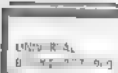
### Assertion and Reason

1. (c) Mycorrhiza represents mutualistic symbiosis between fungus and roots of higher plants. Fungus helps in absorption of minerals and water. Fungus also gets food from plant.
2. (e) Fruticose are well branched shrubby lichens with upright and pendulous organization. These are attached to substratum by a discoid structure. Plant body can be divided into prostrate, leafy and lobed thallus.
3. (c) Aflatoxins, are produced by *Aspergillus flavus*. Contaminated food is the main source of infection. This toxin causes aflatoxicosis which may lead to haemorrhage and disease of liver.
14. (c) Fungi are considered ubiquitous i.e., they occur in a variety of habitats. Most of them are moisture loving and terrestrial and few (e.g., *Monoblepharis*) are aquatic. Fungi may be **epiphytic** (i.e., live on plants e.g., *Armillaria*), **saprophytic** (i.e., grow in dead organic matter e.g., *Mucor*), **symbiotic** (i.e., live with association with other plants e.g., lichen, mycorrhiza) and **predacious** (e.g., *Dactyldela*) and parasitic (e.g., *Erysip*) fungi are non-chlorophyllous i.e., devoid of chlorophyll hence cannot prepare their own food. They are heterotrophic and show absorptive type of nutrition.

## Fungi (Multicellular decomposers)

## ET Self Evaluation Test

1. In all members of Ascomycetes, the number of ascospores and their arrangement in an ascus are as follows  
(a) Eight ascospores in a linear order  
(b) Four ascospores in a linear order  
(c) Either eight or four ascospores, but always in a linear order  
(d) Either eight or four ascospores in a linear order or unordered
2. Cleistothecium is present in [RPMT 1999]  
(a) Only in *Aspergillus*  
(b) All Ascomycetes  
(c) *Penicillium* and *Aspergillus*  
(d) Hemi-ascomycetes
3. In mushroom, fungal tissue which formed central part of a gill is [RPMT 1999]  
(a) Stroma (b) Tremma  
(c) Sub-hymenium (d) Hymenium
4. Fungi causing hair loss are [JIPMER 1999]  
(a) Keratophilous (b) Pyrophilous  
(c) Coprophilous (d) None of these
5. Fungi differ from other kingdoms in being [DPMT 2001]  
(a) Unicellular consumer (b) Unicellular decomposers  
(c) Multicellular consumer (d) Multicellular decomposer
6. LSD is obtained from [CPMT 1998; AFMC 2000; BVP 2002; MH CET 2005]  
(a) *Clavatia* (b) *Claviceps*  
(c) *Amantia* (d) *Trichoderma*
7. Aflatoxicosis of poultry is caused by [AIIMS 2000]  
(a) *A. flavus* (b) *A. fumigatus*  
(c) *Candida albicans* (d) *Rhizopus*
8. Which one secretes pheromones for the function [BHU 1994; Pb. PMT 1999]  
(a) *Rhizopus* for formation of zygospore  
(b) All fungi for sexual reproduction  
(c) Yeast for mating  
(d) Plants for growth and development
9. VAM represents [HP PMT 1994; Haryana PMT 1994; CMC 2002; AFMC 2006; WB JEE 2011]  
(a) Saprophytic fungi (b) Symbiotic fungi  
(c) Saprophytic bacteria (d) Symbiotic bacteria
10. Heterothallism in *Mucor* was first reported by [MP PMT 1993; RPMT 1997; BVP 2001, 02]  
(a) Robert Hooke (b) Blakeslee  
(c) Louis Pasteur (d) Fleming
11. Collumella is found in [BHU 1999]  
(a) *Mucor* / *Rhizopus* (b) *Spirogyra*  
(c) Moss (d) Both (a) and (c)
12. In *Mucor* sp. usually isogamy takes between [MP PMT 1997]  
(a) Same strains (b) + and - strains  
(c) Zygospores (d) Microspores
13. What is VAM [MP PMT 2011]  
(a) Endomycorrhizae (b) Ectomycorrhizae  
(c) Both (d) None
14. Motile sperms are absent in [MP PMT 2013]  
(a) *Rhizopus* (b) *Funaria*  
(c) Fern (d) *Cycas*
15. Which pair of the following belongs to basidiomycetes [CBSE PMT 2007]  
(a) Birds nest fungi and Puffballs  
(b) Puffballs and *Claviceps*  
(c) *Peziza* and Stink horns  
(d) *Morchella* and Mushrooms
16. Which of the following structure helps in the respiration of lichens [AIIMS 2002]  
(a) Soredia (b) Cyphella  
(c) Isidia (d) Cephalodia
17. Life cycle of yeast is [RPMT 1999; Odisha JEE 2012]  
(a) Haplodiplobiontic (b) Haplobiontic  
(c) Diplobiontic (d) All of the above
18. Meiosis occur in yeast in  
(a) Ascospores (b) Ascus mother cell  
(c) Ascus (d) None of the above
19. Conidia of *Albugo* are arranged [RPMT 1995]  
(a) Irregularly (b) Acropetally  
(c) Basipetally (d) Intercalary
20. Yeast is important source of [CPMT 1993, 94; BHU 1999; MP PMT 1999]  
(a) Proteins (b) Riboflavin  
(c) Vitamin C (d) Sugars
21. Zoospore of *Albugo* possesses flagella [RPMT 1995, 96]  
(a) Two similar and apical  
(b) Four similar and medium  
(c) Four apical  
(d) Two dissimilar and laterally
22. Lichens multiply by [Odisha JEE 1995]  
(a) Conidia (b) Oidia  
(c) Ascospores (d) Soredia
23. *Claviceps* is a member of [DPMT 2006]  
(a) Ascomycetes (b) Basidiomycetes  
(c) Zygomycetes (d) Phycormycetes
24. A harmful lichen is [MHCET 2001]  
(a) *Lobarla* (b) *Cladonia*  
(c) *Usnea* (d) *Rocella*
25. Sometimes, in yeast, the conjugation takes place between a parent cell and a bud. It is called [KCET 2001; AFMC 2006]  
(a) Isogamy (b) Syngamy  
(c) Pedogamy (d) Parthenogenesis
26. Fusion of gametangia in *Rhizopus* is [AFMC 2002]  
(a) Planogametic copulation (b) Gametangial contact  
(c) Gametangial copulation (d) Spermatogamy



27. In yeast, cell wall contains [AFMC 1999]  
 (a) Amylose and glucose  
 (b) Glucose and mannose  
 (c) Glucose and muramic acid  
 (d) Sucrose and mannose
28. A plant example in which reproductive structures lack a layer of sterile vegetative cells surrounding the egg (BHU 1994, 2008)  
 (a) *Funaria* (b) *Riccia*  
 (c) *Saccharomyces* (d) *Cycas*
29. Yeast is [AIIMS 1997; MP PMT 2010]  
 (a) Purely aerobic  
 (b) Anaerobic  
 (c) Rarely anaerobic  
 (d) Both aerobic and anaerobic
30. Which one of the following is wrongly matched [CBSE PMT (Pre.) 2011]  
 (a) Cassia - Imbricate aestivation  
 (b) Root pressure - Guttation  
 (c) *Puccinia* - Smut  
 (d) Root - Exarch protoxylem
1. (d) Each ascus has 4 to 8 endogenously produced meiospores called ascospores arranged either in linear order (*Neurospora*) or unorderedly (Yeast).  
 2. (c) *Penicillium* and *Aspergillus* have cleistothecium fruiting body.  
 3. (b) Mature gill composed of a central core called trama which is made up of parallel or loosely interwoven hyphae.  
 4. (a) Keratophilous fungi appear on nails, feathers, hairs etc.  
 8. (a) In *Rhizopus*, zygospore formation is induced by the hormones trisporic acid B and C.  
 11. (d) Collumella : It is the structure made up of sterile cells e.g., *Mucor/Rhizopus* and in moss.  
 15. (a) Bird's nest fungi - *Cyathus*, Puffballs - *Lycoperdon clavaria*.  
 18. (c) In class ascomycetes meiosis occurs in ascus mother cell but in yeasts meiosis occurs in zygote and there is no ascus mother cell. Zygote function directly as naked ascus produces ascospores arranged in unordered manner.  
 20. (b) Yeast from brewing industry is harvested and used as a food. It is rich in protein and vitamin-B (Riboflavin).  
 21. (d) In *Albugo* diploid nucleus undergoes meiosis, followed by several mitotic division. After a period of rest, the oospore germinates and produced reniform, biflagellate zoospores.  
 22. (d) Each soridia form a new thallus under favorable condition.  
 24. (c) In hot season, *Usnea* get dry and become highly inflammable. It easily catches fire and causes forest fire.  
 25. (c) In some yeast e.g., *Zygosaccharomyces chevalieri*, the mother and daughter cells fuse to form the zygote and this phenomenon is called pedogamy.  
 29. (d) Yeast are facultative aerobes i.e., they are anaerobes but also survive under aerobic conditions and respire aerobically as well.  
 30. (c) *Puccinia* - rust fungi

## Answers and Solutions

1	d	2	c	3	b	4	a	5	d
6	b	7	a	8	a	9	b	10	b
11	d	12	b	13	a	14	a	15	a
16	b	17	d	18	c	19	c	20	b
21	d	22	d	23	a	24	c	25	c
26	c	27	b	28	c	29	d	30	c

\* \* \*



## Chapter 1.5

# Viruses

The term 'virus' has been derived from Latin, which means poison or venom or viscous fluid. They remain inactive outside a living host but become active inside the host and multiply in it. They represent a transitional form of life between non-living and living world.

Luria (1953) defined virus as "Sub-microscopic entities capable of being introduced into specific living cells and reproducing inside such cells only. "Single virus is called 'Virion', most of the plant virus are RNA virus. Most of the animal virus are DNA virus.

### (i) Important discovery of virus

**Carolous causius (1576)** recorded first viral disease in tulips.

**A. Mayer (1886)** found a disease in tobacco caused by virus and called it tobacco mosaic disease

**D. Ivanowski (1892)**, a Russian Botanist, discovered the infectious nature of the viruses. He was the person, who discovered the virus.

**Beijerinck (1898)** Beijerinck called them living infectious fluid or "Cotagium virum fluidum."

**W. Twort (1915) and D. Herelle (1917)** discovered bacteriophages, a kind of virus which infected bacteria and destroyed them.

**W. M. Stanley (1935)** first time isolated tobacco mosaic virus (TMV) in crystalline form and showed that crystals were made up of proteins. Nobel prize was awarded to him for this work.

(ii) **Nature of viruses** : Viruses are regarded as intermediate between non-living entities and living organisms. It is very difficult to ascertain whether they are living or non-living. Some characters of viruses suggest their non-living nature where as many other characters suggest their living nature. The two views are listed below –

**Viruses are non-living** : The following characters state that they are non-living.

(a) Viruses have no complete cellular structure. They are not surrounded by cell membrane or cell wall.

(b) They do not show cellular metabolism and lack respiration.

(c) They possess high specific gravity unlike living organisms.

(d) Viruses are active only when they are inside the living host cells. Outside the host, they are good as chemical substances. Thus, they do not have their independent existence.

(e) Postulates of *Robert Koch* are not true for the viruses. Virus cannot grow in "in vitro" condition in lab.

(f) Absence of growth and division.

**Viruses are living organisms** : The following characters state that they are living organisms –

(a) They have definite shape and morphology like that of a living organism.

(b) They possess genetic material (DNA or RNA), which determine their structure and development. Genetic material passes from generation to generation in usual manner.

(c) All viruses are intracellular obligate parasite and attack specific hosts. The bacteriophages recognise the real bacterial surface.

(d) They show property of mutation.

(e) They show irritability and respond to environmental conditions such as heat, ultraviolet rays, humidity, drought, alcohol, etc.

(f) They can grow inside the host and multiply enormously showing one of the most important property of living organisms.

(iii) **Chemical composition** : Chemically viruses are nucleoproteins. They are made up of central core of nucleic acid. Nucleic acid is only one, either DNA or RNA. This nucleic acid

(DNA or RNA) represents the genetic characters of virus. TMV has RNA (like most plant viruses have) 10% RNA and 90% protein is present in influenza virus and PSTV (Potato Spindle Tuber Viroid) also has RNA but it does not have capsid (protein coat). Plant viruses contain RNA but in cauliflower mosaic virus contain DNA. Bacteriophages contain DNA and almost half animal viruses contain RNA and half contain DNA. But it is called that often animal viruses contain DNA. Cancer causing viruses reovirus contain both RNA and DNA, Only some enzymes are detected in viruses such as – Lysozyme in bacteriophages, transcriptase in vaccinia virus, reverse transcriptase and DNA or RNA polymerase in retroviruses.

**Table : 1.5-1 Nucleic acid in viruses and no. of strands**

DNA Viruses	Strands	RNA Viruses	Strands
Adenoviruses	DNA (2)	Avian leukemia virus	RNA (1)
Bacteriophage $\phi$ X 174	DNA (1)	Bacterial virus F2	RNA (1)
Bacteriophage M13	DNA (1)	Bacteriophage MS-2	RNA (1)
Coliphage lambda ( $\lambda$ )	DNA (2)	Coliphage R17	RNA (1)
Coliphage T2, T4, T6	DNA (2)	Influenza virus	RNA (1)
Coliphage T3, T7	DNA (2)	Poliomyelitis virus	RNA (1)
Pox virus	DNA (2)	Tobacco mosaic virus (TMV)	RNA (1)
Herpes viruses	DNA (2)	Reovirus	RNA (2)
Papilloma virus	DNA (2)	Rice dwarf virus	RNA (2)
Polyoma virus SV 40	DNA (2)	Wound Tumour virus	RNA (2)

(iv) **Shape** : There is variation in shapes of viruses. On the basis of shape of viruses have been placed in the following categories.

(a) Straight, rigid rods with helical architecture, e.g. *TMV*, *Barley stripe mosaic virus* (BSMV).

(b) Long flexuous thread-like rods, e.g. *Potato latent mosaic*, *Wheat streak mosaic virus*.

(c) Polyhedral virions, e.g. *Turnip yellow mosaic*, *Tobacco ring spot virus*.

(d) Tadpole like – *Bacteriophages*.

(e) Spherical – *Influenza virus*

(v) **Size** : Viruses have a long range of size. They range from 10 m $\mu$  to more than 300 m $\mu$  in size. The virus of foot and mouth disease (FMD) of animals is smaller than the largest protein molecule. Largest virus is smallpox virus – variola (250 m $\mu$ ).

(vi) **General structure of virus**

Structurally viruses are made up of envelope, capsid, nucleoid and occasionally one or two enzymes.

**Envelope** : Some viruses possess an outer thin loose covering, called envelope. It is composed of proteins (from virus), lipids and carbohydrates (both from host). It is found in some animal viruses e.g., Herpes virus, HIV. The smaller subunits of envelope are called **peplomers**. The viruses, which do not possess envelope, are called naked.

**Capsid** : It is the protein coat that surrounds the central portion of nucleoid and enzymes (if present). The capsid consists of a specific number and arrangement of small sub-units called capsomeres. These sub-units possess antigenic properties.

**Nucleoid** : The nucleic acid present in the virus is called nucleoid. It is the infective part of virus which utilizes the metabolic machinery of the host cell for synthesis and assembly of viral components. The genetic material of viruses are of four types :

(a) Double stranded DNA (ds DNA) e.g., Herpes virus, Hep. B virus.

(b) Single stranded DNA (ss DNA) e.g., Coliphage.

(c) Double stranded RNA (ds RNA) e.g., Wound tumour virus.

(d) Single stranded RNA (ss RNA) e.g., Retrovirus, TMV, Polio virus

(vii) **Life cycle** : The word reproduction is not appropriate in case of viruses because they have no cellular components or cell organelles. They do not reproduce themselves but divide by a special mechanism as follows.

**Attachment** : The bacteriophage gets attached to bacterial cell wall with the help of caudal fibres.

**Penetration** : Bacteriophage dissolves the bacterial wall by an enzyme *Lysozyme* and makes a pore in cell wall. Through this pore DNA molecule enters in the cell after contraction of head protein, entire protein coat remains outside.

**Latent period** : Phage DNA controls hosts cellular machinery. Instead of formation of bacterial protein, phage protein formation begins. Cellular DNA and RNA is broken down and from this cellular DNA, phage DNA is formed. Now protein covers the DNA fragments to form a kid virus.

**Maturation** : This young virion is changed into an adult virus hence this process is called maturation.

**Release** : The viruses are mature, cell wall of bacterial cell is weakened by enzyme *lysozyme*. The release of viruses takes place by bursting of host cell and these are again ready for next infection or attack on other bacteria.

(viii) **Economic importance of viruses**

**Uses of viruses**

(a) Specific viral strains are cultured and attenuated to be used as vaccines against specific diseases.

(b) The addition of cyanophages LPP-1 and SM-1 are useful in controlling water blooms.

(c) Bacteriophage was used by *Hershey* and *Chase* to prove that DNA is the chemical basis of heredity.

(d) Bacteriophages are of interest to geneticists because these bring about transduction.

(e) Water of river Ganga is believed to have phages which destroy bacteria. That is why its water does not get spoiled.

**Tobacco mosaic virus (TMV) :** It was discovered by the Russian worker D. Ivanowski. Franklin et al (1957) described the ultrastructure of (TMV) – It is a rod-shaped virus having a central core of RNA surrounded by protein coat (capsid) to form the nucleocapsid. The nucleocapsid may be naked or may be surrounded by a loose membranous envelope. The protein coat (capsid) consists of 2130 identical subunits (capsomeres).

**Bacteriophage :** The viruses which attack bacteria are called bacteriophages. In outline they look like tadpole or sperm. The body can be divided into a hexagonal head neck and a tail. The hexagonal head has a central core of DNA, which is surrounded by protein coat. The DNA is double helix. The cylindrical tail is hollow and is entirely made up of proteins. At the end of this, there are six long threads called tail fibres or caudal fibres. These fibres help the virus while attaching to bacteria. Bacteriophage contain lysozyme enzyme.

**Cyanophages :** Generally some of the viruses are found which attack on blue green algae. Sofferman and Morris (1963) reported 11 filamentous forms of blue green algae (Lyngbya, plectonema and phormidium, hence called LPP-1) which were attacked by viruses. These viruses are usually called cyanophages. Cyanophages contain DNA as their genetic material. These viruses resemble with bacteriophages in morphology and behaviour.

**Mycophages :** Some fungi such as, Mushrooms, *Penicillium*, etc have also been found to be infected by viruses. These are isometric in shape and contain double stranded RNA.

**Phycophages :** These are virus which attack on Algae.

**Viroids :** Diener and Raymer (1967) discovered very simple smallest infectious agents called Viroids. Viroids consist of RNA only and capsid is lacking. Viroids contain only very low mol. weight. Diener and Raymer reported that causal agent of potato spindle tuber disease was a free RNA and no viral nucleoprotein particles were present in the infected tissue. T.O. Diener (1971) termed it viroid. Viroids are single-stranded, covalently closed circular as well as linear RNA molecules. Transmission is mechanical. The symptoms on host plants are almost similar to those of viruses. Viroids cause persistent infections. A number of other diseases caused by viroids are – Cadang Cadang of coconut, Cucumber pale fruit, Chrysanthemum stunt, Avocado sunblotch, etc.

**Prions :** Prusiner (1982) discovered it as a human disease causal agents. Stanley B. Prusiner discovered infectious agents

which were prions. Prions are proteinaceous particles thought to cause a number of diseases including the slow virus diseases, therefore also called as **slow viruses**. They are made of protein molecules only. Genetic material (DNA and RNA) is absent in prions. Kuru, a disease of central nervous system found in few canniblastic tribes of New Guinea is caused by prions.

**Interferons :** G.M. Findley and McCallum (1937) reported a phenomenon called viral interference in which the cell infected with one type of virus becomes resistant to super infection by other viruses. Alliac Issacs and Lindeman (1957) gave the term interferons to the chemical substances responsible for viral interference.

- (i) Interferons are produced by cells in mammals, rodents, birds, etc., and provide resistance against viruses.
- (ii) Interferons are protein molecules or polypeptides of low molecular weight which prevent viral multiplication.

**Table : 1.5-2 Families of animal viruses, grouped by type of nucleic acid**

Family	Virion Structure	Diameter (nm)	Examples (Diseases)
<b>dsDNA</b>			
Papova virus	Naked polyhedral	40-57	Papilloma (human warts, cervical cancer); polyoma (tumors in certain animals).
Adeno virus	Naked polyhedral	70-80	Viruses that cause respiratory disease; some that cause tumors in certain animals
Herpes virus	Enveloped polyhedral	150-250	Herpes simplex I (cold sores); herpes simplex II (genital), varicella zoster (chicken pox, shingles); Epstein-Barr virus (infectious mononucleosis, Burkitt's lymphoma).
Pox virus	Enveloped complex	200-350	Varicella (smallpox); vaccinia; cowpox
<b>ss DNA</b>			
Parvo-virus	Naked polyhedral	18-26	Most depended on co infection with adenoviruses for growth

**Table : 1.5-3 ss RNA that can serve as mRNA  
(+ strand RNA)**

Picorna virus	Naked polyhedral	18-38	Poliovirus, rhinovirus (common cold), enteric viruses
Toga virus	Enveloped polyhedral	40-60	Rubella virus; yellow fever virus; encephalitis virus (transmitted by insects)
Retrovirus	Enveloped polyhedral; two copies of genome per virion	100-120	RNA tumor viruses (solid tumors and leukemia); AIDS

**Table : 1.5-4 ss RNA that is a template for mRNA  
(- strand RNA)**

Rhabdovirus	Enveloped helical	70-180	Rabies
Paramyxovirus	Enveloped helical	150-300	Measles, mumps
Orthomyxovirus	Enveloped helical; RNA in eight segments.	80-200	Influenza viruses
<b>ds RNA</b>			
Reovirus	Naked polyhedral, RNA in ten segments.	60-80	Dianthaea viruses

\*ds = double-stranded; ss = single-stranded.

**Table : 1.5-5 Important plant diseases caused by viruses**

S.No.	Disease	Causal organism
(1)	Abutilon mosaic	Abutilon mosaic virus
(2)	Bunchy top of banana	Banana bunchy top virus
(3)	Cucumber mosaic	Cucumber mosaic virus
(4)	Little leaf of brinjal	Brinjal little leaf virus
(5)	Little leaf of cotton	Cotton little leaf virus
(6)	Papaya mosaic	Papaya mosaic virus
(7)	Potato leaf roll	Potato leaf roll virus
(8)	Potato mild mosaic	Potato virus X
(9)	Potato rugose mosaic	Potato virus X and Y
(10)	Stunt of S. C.	Ratoon stunt virus
(11)	Rosette of groundnut	Groundnut mosaic virus
(12)	Sugarcane mosaic	Sugarcane virus I
(13)	Tobacco mosaic	Tobacco mosaic virus
(14)	Tomato leaf curl	Tomato curl virus
(15)	Tristeza of citrus	Citrus Tristeza virus

**Table : 1.5-6 Important human diseases caused by viruses**

S.No.	Disease	Host	Causal organism
(1)	Encephalitis	Man	Encephalitis virus
(2)	Infectious hepatitis	Man	Hepatitis virus
(3)	Herpetic Keratitis	Man	Herpes virus
(4)	Influenza	Man	Influenza virus-a
(5)	Measles	Man	Measles virus
(6)	Viral bronchitis	Man	Parainfluenza virus
(7)	Poliomyelitis	Man (children)	Polio virus
(8)	Small Pox	Man	Pox virus
(9)	Common cold	Man	Rhino virus
(10)	Yellow fever	Man	Yellow fever virus

## Tips & Tricks

✍ Father of Virology W.M. Stanley (American Microbiologist).  
✍ Edward Jenner (1796) developed the first successful vaccine against viral disease small pox.

✍ D' Herelle (1917) coined the term "bacteriophage" for bacterial virus.

✍ Caulimo virus (cauliflower mosaic virus) are double stranded DNA virus

✍ Lindemann (1957) did the first successful vaccination against Polio.

✍ Single virus observed under electron microscope, outside host is called "Virion".

✍ The first virus to be cultured in human cells was Polio virus.

✍ Most of the phase are DNA virus.

✍ Retroviruses and reverse transcription were reported by Temin and Baltimore

✍ Viruses can pass through bacteria proof filters. These are the intermediate connection between living and non living.

✍ Viruses have host specificity. A specific virus infects only a particular host.

✍ In the world which do not have cell are virus, viroids and prions.

✍ Substance which can inactivate to viral activities are known as antiviral agents or virucide.

✍ The synthesis of viral proteins takes place on host ribosomes.

✍ Viruses lack pigments metabolic activity, they are made up of RNA the only movement and sex organ, but some enzymes are found in them.

✍ AIDS is caused by HIV. It infects T-lymphocytes. HIV virus remains dormant for about 8 years. Infected person does not suffer a symptoms during this period. AIDS day is 1<sup>st</sup> December.

✍ Size of virus is 20nm - 300 nm Largest virus is - vaccinia or cow pox-virus (500nm). Smallest virus is - Alfa-alfa virus (17 nm).

✍ Pox virus is also known as vip virus

✍ Five genes are present in a simplest virus.





## Ordinary Thinking

## Objective Questions

## Viruses

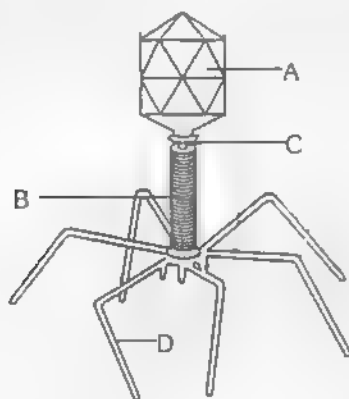
1. The first to isolate plant virus was  
[NCERT; CBSE PMT 1993]  
Or  
The Tobacco mosaic virus was crystallized for first time by  
[MP PMT 1994]  
(a) W.M. Stanley (b) E. C. Stackmann  
(c) A. K. Smith (d) Ivanowski
2. The viruses contain [NCERT; J & K CET 2008]  
(a) Proteins only  
(b) DNA only  
(c) Nucleic acids only  
(d) Proteins, DNA or RNA (nucleic acids)
3. Caulimo virus (Cauliflower mosaic virus) are a group of viruses which have  
(a) Double stranded RNA (b) Single stranded RNA  
(c) Single stranded DNA (d) Double stranded DNA
4. The rabies virus consists of [WB JEE 2009]  
(a) Single stranded RNA (b) Double stranded RNA  
(c) Single stranded DNA (d) Double stranded DNA
5. A virus containing ssRNA act as a template for DNA synthesis is called as  
[MP PMT 2007; DPMT 2007; Odisha JEE 2008]  
(a) Polio virus (b) Retro virus  
(c) Pox virus (d) Adeno virus
6. Viruses enter plant cells only through..... [VITEEE 2008]  
(a) Lenticels (b) Wounds  
(c) Stomata (d) Roots
7. Influenza virus has got  
(a) Naked capsid (b) Enveloped capsid  
(c) Naked polyhedral capsid (d) No capsid at all
8. The genetic material in viruses is [NCERT; CPMT 1994; MP PMT 1995, 98, 2000; CBSE PMT 1997; Pb. PMT 2000; BHU 2005]  
(a) Only RNA  
(b) Only DNA  
(c) RNA and DNA both  
(d) RNA or DNA i.e. one nucleic acid in a virus
9. Each capsomere of TMV contain amino acids whose number is  
(a) 158 (b) 185  
(c) 815 (d) 581
10. Ribovira is a group of viruses which contains  
(a) dsDNA (b) ssDNA  
(c) RNA (d) None of these
11. Which of the following is the smallest virus  
(a) Foot and mouth virus  
(b) Tobacco mosaic virus  
(c) Coliphage lambda virus  
(d) Wound tumour virus
12. Which of the following is the largest virus  
(a) *Penicillium virus* (b) Wound tumour virus  
(c) Pox virus (d) None of the above
13. Which of the following is false [CBSE PMT 2005; DUMET 2009]  
(a) Most plant viruses are RNA viruses  
(b) Most animal viruses are DNA viruses  
(c) TMV has double stranded RNA molecule  
(d)  $T_4$  bacteriophage has double stranded DNA molecule
14. Which one is absent in viruses [AFMC 2008]  
(a) Replication (b) Protein synthesis  
(c) Energy liberation (d) Mutation
15. Wound tumour virus has  
(a) Double stranded DNA (b) Single stranded DNA  
(c) Double stranded RNA (d) Single stranded RNA
16. Which of the following is a DNA containing plant virus [Pb. PMT 1999, 2000]  
(a) Tobacco mosaic virus (b) Tomato mosaic virus  
(c) Cauliflower mosaic virus (d) Potato mosaic virus
17. Algal viruses are known as [CBSE PMT 1993]  
(a) Binal viruses (b) Cyanophages  
(c) Mycophages (d) Phycophages
18. Arthropod borne viruses are  
(a) Ribo virus (b) Reo virus  
(c) Arbo virus (d) None of these
19. Which one of the following are intracellular obligate parasites [KCET 1998; DUMET 2009]  
(a) Bacteria (b) Viruses  
(c) Slime moulds (d) Blue-green algae
20. Select the wrong statements [AIPMT 2015]  
(a) W.M. Stanley showed that viruses could be crystallized  
(b) The term '*contagium vivum fluidum*' was coined by M.W. Beijerinck  
(c) Mosaic disease in tobacco and AIDS in human being are caused by viruses  
(d) The viroids were discovered by D.J. Ivanowski
21. Helper virus is called  
(a) Perfect phage of virus  
(b) A defective phage which helps another defective phage  
(c) A latent phage  
(d) None of these
22. Who discovered interferons  
(a) Issacs and Lindmann (b) Holmes and Knight  
(c) Harshey and Chase (d) Enders

23. The agents which are known to cause CJD are [KCET 2009]  
 (a) Protein particles (b) A class of bacteria  
 (c) A class of viruses (d) Fungi
24. Virus was discovered by whom [WB JEE 2009]  
 (a) Stanley (b) Ivanowski  
 (c) Herelle (d) Beijerinck
25. A virion is a [Odisha JEE 2009]  
 (a) Without protein coat virus  
 (b) Enucleated virus  
 (c) Prions  
 (d) Virus
26. Protein of capsomeres is made up of  
 (a) Nucleic acids (b) Carbohydrates  
 (c) Fats (d) Amino acids
27. Who proposed the phanerogram of virus  
 (a) Lwoff and Tournier (b) W.M. Stanley  
 (c) Weil *et al* (d) None of these
28. A cryptogram has got how many pairs of information  
 (a) 1 (b) 2  
 (c) 3 (d) 4
29. In which virus, DNA is double stranded [AMU (Med.) 2006]  
 (a) Hepatitis A (b) Hepatitis B  
 (c) Hepatitis C (d) Hepatitis D
30. Viroids differ from viruses in having [NEET 2017]  
 (a) DNA molecules with protein coat  
 (b) DNA molecules without protein coat  
 (c) RNA molecules with protein coat  
 (d) RNA molecules without protein coat
31. Virus was assigned its name by  
 (a) Dmitri Ivanowski (b) Adolf Mayer  
 (c) M.W. Beijerinck (d) McKinney
32. The filterable property of tobacco mosaic virus (TMV) was shown by [NCERT; MP PMT 1996]  
 (a) Ivanowsky (b) Beijerinck  
 (c) Stanley (d) Winogradsky
33. Viruses were called *Contagium vivum fluidum* by [NCERT]  
 (a) de Herelle (b) Bawden and Pirie  
 (c) Twort (d) Beijerinck
34. The size of TMV is  
 (a)  $17.5 \times 300\text{\AA}$  (b)  $17.5 \times 300\text{nm}$   
 (c)  $19.5 \times 250\text{\AA}$  (d)  $19.5 \times 250\text{nm}$
35. Which of the following is not concerned with viruses  
 (a) Viruses are made up of nucleic acid and proteins  
 (b) Viruses multiply only in living host cell  
 (c) Viruses can not use oxygen for respiration  
 (d) Viruses can be grown in sugary liquid
36. The viruses are known as  
 (a) Unicellular (b) Acellular  
 (c) Multicellular (d) Free genes
37. A substance (low molecular weight protein) produced by host cells in response to viral infection and protect other cells against further viral infection is  
 (a) Phytotoxin (b) Antibody  
 (c) Interferon (d) Hormone
38. Which is not true for viruses  
 (a) Double stranded DNA (b) Double stranded RNA  
 (c) Both DNA and RNA (d) Single stranded DNA
39. Single stranded nucleic acid is found in [BVP 2004]  
 (a) *E. coli* (b)  $\phi \times 174$   
 (c)  $\lambda$  (d)  $T_4$
40. Temin worked on which virus [BHU 2000]  
 (a) Herpesvirus (b) Rhinovirus  
 (c) Retrovirus (d) Denguvirus
41. The capsid of tobacco mosaic virus (TMV) has capsomeres numbering [KCET 2000]  
 (a) 1230 (b) 2130  
 (c) 2310 (d) 3120
42. Genetic material of reovirus is [Kerala CET 2001; Odisha JEE 2004, 11]  
 (a) ds DNA (b) ss DNA  
 (c) ds RNA (d) ss RNA
43. Viruses multiply  
 (a) *In vivo* (b) *In vitro*  
 (c) Both (a) and (b) (d) None of the above
44. The viruses responsible for causing polio and hydrophobia are  
 (a) Neurotropic (b) Visotropic  
 (c) Dermotropic (d) Neumotropic
45. The part of the virus which gives to it the hereditary feature, is [BHU 1994; BVP 2003]  
 (a) Capsid (b) Capsomere  
 (c) Nucleic acid (d) Nucleotide
46. Influenza is caused by [NCERT; BVP 2001]  
 (a) Bacterium (b) Virus  
 (c) Fungus (d) Cyanobacterium
47. Vertical transmission of virus in human is through  
 (a) Placenta of mother (b) Sperms of the father  
 (c) Both (a) and (b) (d) None of these
48. The causative agent of mad-cow disease is a [CBSE PMT 2006]  
 (a) Worm (b) Virus  
 (c) Bacterium (d) Prion
49. Viruses multiply in [EAMCET 1995; BVP 2001; BHU 2004]  
 (a) Bacteria only (b) All living cells  
 (c) Specific living cells (d) Rotten food
50. Which of the following is true for viruses  
 (a) They invariably contain DNA  
 (b) They multiply only in host cell  
 (c) They occur only inside bacteria  
 (d) Their genetic material is RNA

51. HIV is classified as a retrovirus because its genetic information is carried in [DUMET 2009,10]

(a) DNA instead of RNA (b) DNA  
(c) RNA instead of DNA (d) Protein coat

52. Given below is the diagram of a bacteriophage. In which one of the options all the four parts A, B, C and D are correct



Options: [NCERT; CBSE PMT (Mains) 2010]

	A	B	C	D
(a)	Tail fibres	Head	Sheath	Collar
(b)	Sheath	Collar	Head	Tail fibres
(c)	Head	Sheath	Collar	Tail fibres
(d)	Collar	Tail fibres	Head	Sheath

53. Viruses usually infect the whole plant except the [CBSE PMT 1993; MH CET 2000]

(a) Stem apex (b) Cortex  
(c) Pith (d) Phloem

54. Potato tuber spindle disease is caused by [MP PMT 2007; DUMET 2009; BHU 2012]

(a) Virus (b) Viroid  
(c) Plasmid (d) None of these

55. Which one the following virus contains both DNA and RNA [WB JEE 2010]

(a) Cyanophage (b) Herpes virus  
(c) Leuko virus (d) Polio virus

56. Grey matter of brain is affected by

(a) Measles virus (b) Varicella virus  
(c) Dengue fever virus (d) Encephalitis virus

57. X-bodies are formed during infection of

(a) Bacteria (b) Mycoplasma  
(c) Virus (d) All the above

58. Infectious proteins are presents in

[MP PMT 2007; CBSE PMT (Pre.) 2010]

(a) Satellite viruses (b) Gemini viruses  
(c) Prions (d) Viroids

59. Our crops suffer from many diseases. Indicate the disease caused by virus

(a) Potato mosaic (b) Citrus canker  
(c) Brown rot of potato (d) Leaf spot of cotton

60. Banana bunchy top is caused by [KCET 2011]

(a) *Mycoplasma*  
(b) *Deutromycetes*  
(c) *Xanthomonas*  
(d) *Pentalonia nigronervosa* (Virus)

61. Interferon suppresses the pathogenic activity of

[CMC Vellore 1994; MP PMT 1998;

MHCET 2000; BVP 2000, 04]

(a) Bacteria (b) Viruses  
(c) Protozoans (d) Helminths

62. Tobacco mosaic Virus (TMV) has

[EAMCET 1993, MHCET 2001; MP PMT 2001;

BVP 2002; AIEEE Pharmacy 2004; J & K CET 2008]

(a) A single stranded RNA molecule  
(b) A double stranded RNA molecule  
(c) A single stranded DNA molecule  
(d) A double stranded DNA molecule

63. Viruses that infect bacteria, multiply and cause their lysis, are called [CBSE PMT 2004; AIIMS 2009]

(a) Lytic (b) Lysogenic  
(c) Lysozymes (d) Lipolytic

64. Phages that show lysogenic cycle are called

[MP PMT 1997; VITEEE 2008]

(a) Temperate phages (b) Virulent phages  
(c) Avirulent phages (d) Lytic phages

65. A bacteriophage is [MP PMT 1995, 98, 2002, 10, 12; MHCET 2000; Odisha JEE 2009; WB JEE 2010]

(a) A virus attacking a bacterium  
(b) A bacterium attacking a virus  
(c) A stage in the life-cycle of bacterium  
(d) A virus attacking another virus

66. Tailed bacteriophages are [CBSE PMT 1995]

(a) Motile on surface of bacteria  
(b) Non-motile  
(c) Actively motile in water  
(d) Motile on surface of plant leaves

67. Which of the following is a pandemic disease

(a) Amoebic dysentery (b) Hepatitis  
(c) Filariasis (d) Influenza

68. Sometimes when a virus attacks a bacterium, neither the virus multiplies nor the bacterium dies. This phenomenon is called as [MP PMT 1998]

(a) Adsorption (b) Assimilation  
(c) Lysogeny (d) Viral stability

69. On the basis of host attacked viruses are classified into

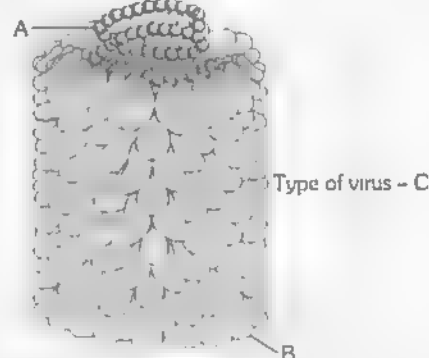
[MP PMT 1995]

(a) Two types (b) Three types  
(c) Four types (d) Five types

70. The spread of AIDS disease is promoted by [MP PMT 1995]  
 (a) Homosexuality  
 (b) Immoral way of life  
 (c) Use of infected needles in blood transfusion  
 (d) All the above
71. Find out the correct statement [MP PMT 1996; Kerala PMT 2011]  
 (a) In lichens, the algal component is called phycobiont and fungal component is known as mycobiont, which are heterotrophic and autotrophic respectively  
 (b) Viroid contains RNA of low molecular weight and protein coat  
 (c) A virus contains both RNA and DNA  
 (d) Viruses are obligatory parasites  
 (e) Viruses that infect plants have double stranded RNA
72. Dog distemper is a disease carried by a [KCET 2011]  
 (a) Bacterium (b) Viroid  
 (c) Prion (d) Virus
73. Influenza virus has [CBSE PMT 1996]  
 (a) RNA (b) DNA  
 (c) Neither RNA nor DNA (d) Both DNA and RNA
74. Which is not found in bacteriophage [Bihar CECE 2006]  
 (a) RNA (b) DNA  
 (c) Coat (d) Protein
75. Viral genome incorporated host DNA is called [BHU 2006; Odisha JEE 2010; WB-JEE 2016]  
 (a) Prophage (b) Prophage  
 (c) Bacteriophage (d) None of these
76. Potato leaf-roll disease is caused by [MP PMT 1993, 99, 2002]  
 (a) Mycoplasma (b) Virus  
 (c) Microspores (d) Bacterium
77. A provirus is  
 (a) Precursor of a viral particle  
 (b) Prolonged viral infection  
 (c) A symbiotic viral nucleic acid within the host genome  
 (d) A dormant viral protein
78. Bacteriophage is made up of [CPMT 1994; Pb. PMT 2000]  
 (a) Carbon and nitrogen  
 (b) DNA  
 (c) Nucleoprotein (Nucleic acid + protein)  
 (d) Protein only
79. Which one is the smallest among the following  
 (a) Bacteriophage (b) TMV  
 (c) *E. coli* (d) *Neurospora*
80. Plant virus was first crystallized by [MP PMT 1994; CPMT 1996]  
 (a) Pirie (b) Bawden  
 (c) Stanley (d) Beijerinck
81. Which of the bacteriophage is a virulent  
 (a) Coliphage  $M_{12}$  (b)  $\lambda$  phage  
 (c)  $T_4$  phage (d) None of these
82. The enzymes formed by bacteriophage which ruptures the bacterial wall is  
 (a) Proenzymes (b) Phage-lysozymes  
 (c) Endolysins (d) Phagoproteins
83. Which of the following sequence is found in *Rous sarcoma virus*  
 (a) DNA  $\rightarrow$  RNA  $\rightarrow$  Protein  
 (b) RNA  $\rightarrow$  RNA  $\rightarrow$  Protein  
 (c) RNA  $\rightarrow$  DNA  $\rightarrow$  RNA  $\rightarrow$  Protein  
 (d) DNA  $\rightarrow$  DNA  $\rightarrow$  Protein
84. Which of the following shows coiled RNA strand and capsomeres [CBSE PMT 2014]  
 (a) Measles virus (b) Retrovirus  
 (c) Polio virus (d) Tobacco mosaic virus
85. The protein coat of virus is called [NCERT; BHU 1999; WB JEE 2009; MP PMT 2009; CBSE PMT (Pre.) 2010]  
 (a) Capsid (b) Cosmid  
 (c) Capsomere (d) Chromophore
86. The phage which does not destroy the host cell but infects it, is called  
 Or  
 The virus responsible for lysogenic growth cycle is  
 (a) Cyanophage (b)  $T_2$  phage  
 (c) Virulent phage (d)  $\lambda$  phage
87. Which of the following was used by Hershey and Chase to prove that DNA is the chemical basis of heredity [AIIMS 1993; BVP 2003]  
 (a) TMV (b) Cauliflower mosaic virus  
 (c) Dahlia mosaic virus (d)  $T_2$  bacteriophage
88. Genetic mapping of bacteriophage  $\phi \times 174$  has been done by  
 (a) Pirie and Bawden (b) F. Sanger  
 (c) R.L. Sinsheimer (d) Salk and Sabin
89. Coliphage  $T_2$  has [AFMC 1997]  
 (a) ssRNA (b) ssDNA  
 (c) dsRNA (d) dsDNA
90. Which of the following viruses is devoid of protein coat with their body constituted by only RNA  
 (a) Tobacco mosaic virus (TMV)  
 (b) Potato spindle tuber virus (PSTV)  
 (c) Polyoma virus  
 (d) Mumps virus
91. Zymophage remains parasite on  
 (a) Bacteria (b) Algae  
 (c) Yeast (d) None of these

92. The virus of *deoxyvira* (sub-phylum) contains  
(a) mRNA (b) tRNA  
(c) DNA (d) rRNA
93. An extreme example of latency in which DNA of the phage is integrated with the DNA of host cell chromosome is  
[DPMT 1993]  
(a) Lysis (b) Lysogeny  
(c) Attenuated virus (d) Prophage
94. In cyanophage, the genetic material is  
(a) RNA (b) DNA  
(c) RNA and DNA (d) Protein
95. Satellite virus is a  
(a) Independent virus  
(b) Associated with an activator virus  
(c) Both (a) and (b)  
(d) None of these
96. Ultrastructure of bacteriophage-T was studied by  
(a) R.L. Sinsheimer (b) S. Brenner  
(c) M. Schlesinger (d) None of the above
97. The water of Holy Ganga, river is pure due to the presence of  
[MP PMT 1998]  
(a) Cyanophages (b) Hydrophytes  
(c) Bacteria (d) Bacteriophages
98. Viroids have  
[MHCET 2001; AIEEE Pharmacy 2004; J & K CET 2012]  
(a) Double stranded RNA enclosed by protein coat  
(b) Double stranded DNA enclosed by protein coat  
(c) Single stranded DNA not enclosed by protein coat  
(d) Single stranded RNA not enclosed by protein coat
99. Which statement is wrong for viruses  
[CBSE PMT (Pre.) 2012]  
(a) All are parasites  
(b) All of them have helical symmetry  
(c) They have ability of synthesize nucleic acids and proteins  
(d) Antibiotics have no effect on them
100. The genome of transducing phages is  
[JIPMER 2001]  
(a) Single stranded RNA (b) Double stranded RNA  
(c) Single stranded DNA (d) Double stranded DNA
101. A single stranded DNA molecule is the genetic material of bacteriophage  
[BHU 1995, 2000; MHCET 2000; DPMT 2003, 04]  
(a)  $T_2$  (b)  $T_4$   
(c)  $\phi \times 174$  (d)  $\lambda$
102. Which of the following diseases are known to be caused by viruses (In this item one or more of the answers given may be correct. Decide which are correct and mark the answer sheet according to the code)  
1. Burkitt's lymphoma  
2. Adult T-cell leukemia  
3. Phenyl ketonuria  
**Code**  
(a) 1, 2 and 3 are correct (b) Only 1 and 2 are correct  
(c) Only 2 and 3 are correct (d) Only 1 and 3 are correct

103. Which of the following statements is not true for retroviruses  
[CBSE PMT 2004]  
(a) The genetic material in mature retroviruses is RNA  
(b) Retroviruses are causative agents of certain kinds of cancer in man  
(c) DNA is not present at any stage in the life cycle of retroviruses  
(d) Retroviruses carry gene for RNA-dependent DNA polymerase
104. In phage (plaque) culture  
[CMC Vellore 1993]  
(a) Only protein of virus enters and multiplies  
(b) Only DNA of virus enters the bacterium and multiplies  
(c) Whole virus enters the bacterium and multiplies  
(d) None of these
105. Satellite RNA are present in some  
[NEET (Karnataka) 2013]  
(a) Viroids (b) Prions  
(c) Bacteriophages (d) Plant viruses
106. The diagram of a virus is given below. In which of the options A, B and C are correct  
[NCERT]



	A	B	C
(a)	RNA	Protein	HIV
(b)	RNA	Lipid	Tobacco Mosaic Virus
(c)	DNA	Capsid	Tobacco Mosaic Virus
(d)	RNA	Capsid	Tobacco Mosaic Virus

107. Which of the following statements is **wrong** for viroids  
[NEET (Phase-I) 2016]  
(a) They lack a protein coat  
(b) They are smaller than viruses  
(c) They cause infections  
(d) Their RNA is of high molecular weight
108. The genome of Influenza virus is a  
[WB JEE 2016]  
(a) Single-stranded RNA (-) (b) Single-stranded RNA (+)  
(c) Double-stranded RNA (d) Single-stranded DNA



## Critical Thinking

### Objective Questions

1. Viruses are non-cellular organisms but replicate themselves once they infect the host cell. To which of the following kingdom do viruses belong to  
[NCERT]  
(a) Monera (b) Protista  
(c) Fungi (d) None of the above

2. What is the purest form of matter that cannot be separated into different substances by chemical means  
(a) Electrons (b) Molecules  
(c) Elements (d) Compounds
3. Bacteriophage is similar to fungus [CMC Vellore 1993]  
(a) In having DNA as genetic material  
(b) In having RNA as genetic material  
(c) In mode of reproduction  
(d) In having cell wall
4. Interferon is a [MP PMT 1996, 2006; Pb PMT 2000; CBSE PMT 2000, 01; AFMC 2002; DPMT 2003; BHU 2003; MHCET 2003; KCET 2007; VITEEE 2008]  
(a) Low molecular weight protein which inhibits viral multiplication  
(b) RNA used for DNA synthesis  
(c) Protein used for the transportation of oxygen  
(d) Protein inhibits DNA synthesis
5. Which one of the following enzymes is present in the bacteriophage [MP PMT 1996]  
(a) Protease (b) Lysozyme  
(c) Succinic dehydrogenase (d) Urease
6. AIDS virus contains or Human immuno deficiency (HIV) virus has protein coat and genetic material which is [MP PMT 1994, 99, 2003, 09; CBSE PMT 1998; AIIMS 2000, 13]  
(a) Single stranded RNA with protein  
(b) Double stranded RNA  
(c) Single stranded DNA with protein  
(d) Double stranded DNA
7. Viruses have [CBSE PMT 2014]  
(a) Single chromosome  
(b) Both DNA and RNA  
(c) DNA enclosed in a protein coat  
(d) Prokaryotic nucleus
8. Difference between Virus and Viroid is [NCERT]  
(a) Absence of protein coat in viroid but present in virus  
(b) Presence of low molecular weight RNA in virus but absent in viroid  
(c) Both a and b  
(d) None of the above
1. Assertion Interferons are a type of antibodies produced by body cells infected by bacteria.  
Reason Interferons stimulate inflammation at the site of injury. [AIIMS 2008]
2. Assertion DNA serves as hereditary material.  
Reason DNA functions as blue-print for building and running cellular machinery.
3. Assertion Primitive atmosphere was formed by the lightest atoms.  
Reason The primitive atmosphere was reducing in nature.

# Answers

## Viruses

1	a	2	d	3	d	4	a	5	b
6	b	7	b	8	d	9	a	10	c
11	a	12	c	13	c	14	c	15	c
16	c	17	d	18	c	19	b	20	d
21	b	22	a	23	a	24	b	25	d
26	d	27	a	28	d	29	b	30	d
31	c	32	a	33	d	34	b	35	d
36	d	37	c	38	c	39	b	40	c
41	b	42	c	43	a	44	a	45	c
46	b	47	a	48	d	49	b	50	b
51	b	52	c	53	a	54	b	55	c
56	d	57	c	58	c	59	a	60	d
61	b	62	a	63	a	64	a	65	a
66	b	67	d	68	c	69	b	70	d
71	d	72	d	73	a	74	a	75	b
76	b	77	c	78	c	79	a	80	c
81	d	82	c	83	c	84	d	85	a
86	d	87	d	88	b	89	d	90	b
91	c	92	c	93	b	94	b	95	b
96	b	97	d	98	d	99	b	100	d
101	c	102	b	103	c	104	b	105	d
106	d	107	d	108	a				

## Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

- (a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion  
(b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion  
(c) If the assertion is true but the reason is false  
(d) If both the assertion and reason are false  
(e) If the assertion is false but reason is true

## Critical Thinking Questions

1	d	2	c	3	a	4	a	5	b
6	a	7	c	8	a				

## Assertion and Reason

1	d	2	a	3	b
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# Answers and Solutions

## Viruses

19. (b) Viruses are non-cellular, infectious, obligate, intracellular parasites. These are genetic elements (DNA or RNA) wrapped in a protein coat and are not considered to be organisms, as they can not reproduced independently.
21. (b) Helper virus needs another virus to be active.
30. (d) Viruses are made up of proteins and nucleic acids while viroids are naked RNA molecules.
39. (b) Single stranded DNA found in e.g.  $\phi \times 174$ , S-13, F-1, M-13,  $R_{17}$  (Parvo viruses) etc.
40. (c) Temin and Baltimore (1975) discovered the process of reverse transcription. It is found in retrovirus.
41. (b) The protein coat (capsid) consists of 2130 identical subunits (capsomeres) in TMV.
43. (a) Because viruses are obligate parasites, so that they can only survive in living cells not in non-livings
46. (b) Influenza is caused by virus. It is a RNA virus with a helical capsid surrounded by an envelope with spike.
51. (b) Retrovirus is an RNA containing virus that converts its RNA into DNA by means of the enzyme reverse transcriptase ; this enables it to become integrated into its host's DNA. The best known retrovirus is HIV, responsible for AIDS in humans.
52. (c) A – Head, B – Sheath; C – Collar; D – Tail fibre
53. (a) Because in apical tips of shoot apex, a few growth hormones like auxins are formed which check infection of viruses.
55. (c) Leuko virus (a Retro virus) posses both DNA and RNA in their life cycle.
56. (d) Encephalitis virus infects the grey matter of brain and cause swelling in brain known as brain fever.
61. (b) Interferon : In 1957 Issac and Lindeman called interferon to that protein, which is synthesized in human cells during viral infections This protein provide immunity to the same virus or the others also.
75. (b) Viral genome incorporated into host DNA is called prophage. Most of the prohage genes are repressed by two repressor proteins that are the product of phage genes.
78. (c) Bacteriophage is a virus which infect bacteria. In its tadpole like structure, DNA is found inside the proteinous head.

83. (c) *Rous sarcoma virus* : This virus related to retro group of viruses is having genetical material RNA. But this RNA on reaching in host cell synthesize DNA by the process of reverse transcription, which form mRNA and then protein. So the sequence in this is [RNA  $\rightarrow$  DNA  $\rightarrow$  mRNA  $\rightarrow$  Protein]
84. (d) RNA is single stranded helically coiled with 6400 ribonucleotides
86. (d) Lysogenic cycle is the reproductive cycle of a temperate, nonvirulent phage (like  $\lambda$  phage) which has the potential to lyse the host cell but normally involves integration of viral genome with host DNA and multiplication of the same alongwith the host cell.
93. (b) *Lysogeny* : The process in which bacteriophage attacking on host bacteria, after transduction burst the bacterial cell is called as lysogeny.
95. (b) *Satellite virus* : This virus carry some other viruses on his body and behaves like carrier e.g. tobacco mottle virus.
101. (c)  $\phi \times 174$  Bacteriophage : In this bacteriophage, DNA is rounded, closed and bangle shaped, the duplication pattern is different type in this bacteriophage.

## Critical Thinking Questions

2. (c) An element is the simplest form of matter which cannot be split into two or more simpler substances by ordinary chemical methods because an element is formed of only one type of atom.
4. (a) *Interferon* : During infection of viruses on human cells, a protein having 270 amino acids is synthesized known as interferon. This protein helps in developing defence mechanism against the same virus or others also
5. (b) In bacteriophage, enzyme lysozyme helps at the time of dissolving host wall
6. (a) *HIV virus* is a retrovirus which contains single stranded RNA surrounded by protein coat (core shell) as genetic material. It causes AIDS.
7. (c) Nucleoprotein particles

## Assertion and Reason

1. (d)
2. (a) DNA is the genetic material in most of living organism except the plant viruses and some bacteriophages. It is the only molecule which can replicate itself or can form its own carbon copy. The phenomenon is called molecular reproduction. All the information required for growth, differentiation, running cellular machinery and reproduction is contained in DNA molecules. These genetic information of DNA are like the blue print. During cell division (which involve DNA replication) the daughter cell receive the same blue print or genetic material as in the parental cell.
3. (b) The lightest atoms of nitrogen, hydrogen, carbon etc. formed the primitive atmosphere. Hydrogen atoms were most numerous and most reactive in primitive atmosphere. First hydrogen atoms combined with all oxygen atoms to form water and leaving no free oxygen. Thus primitive atmosphere was reducing atmosphere (without free oxygen) unlike the present oxidising atmosphere (with free oxygen). Presence of huge amount of free hydrogen in primitive atmosphere also proves its reducing nature.



## Viruses

## SET Self Evaluation Test

1. Identify the correct sequence of events in the viral replication process.  
 I. Eclipse                      II. Maturation  
 III. Adsorption                IV. Assembly  
 V. Penetration                VI. Lysis  
 [WB JEE 2012]  
 (a) I → II → III → IV → V → VI  
 (b) II → I → III → IV → V → VI  
 (c) III → V → I → II → IV → VI  
 (d) III → V → I → IV → II → VI
2. The genetic material of Papaya Mosaic Virus is  
 [Odisha JEE 2012]  
 (a) ssDNA  
 (b) dsDNA  
 (c) dsRNA  
 (d) ssRNA
3. Who discovered synthesis of DNA from RNA in Rous sarcoma virus  
 (a) Smith  
 (b) Temin  
 (c) Twort  
 (d) Meyer
4. Bacteriophage which infects colon bacterium is  
 (a) Biophage  
 (b) Cyanophage  
 (c) Coliphage  
 (d) None of these
5. Most of the plant viruses are characterized in having  
 [AFMC 1993; DPMT 1993]  
 (a) DNA  
 (b) RNA  
 (c) DNA and RNA  
 (d) Lipids
6. Cyanophages attack  
 [MP PMT 1996, 2004]  
 (a) Cyanobacteria  
 (b) Bacteria  
 (c) Fungi  
 (d) Lichens

## Answers

1	c	2	d	3	b	4	c	5	b
6	a								

\* \* \*



## Chapter

# 1.6

## Plant Kingdom

### Characteristics of Plantae

The term plant is more commonly used for land photoautotrophs with distinct root, stem and leaves. Study of plants is called phytology.

Kingdom plantae includes green, brown and red algae, liverworts, mosses, ferns and seed plants with or without flowers. They have the following characters.

(1) Member of the kingdom are multicellular, eukaryotes. However, unicellular and colonial members of green and red algae are also included in kingdom plantae.

(2) Cells are surrounded by cell wall. It contain cellulose.

(3) Mature cells usually possess a single central vacuole.

(4) Reserve food is starch in green algae and embryophytes, floridean starch in red algae and laminarin in brown algae.

(5) They contain photosynthetic pigment in plastids.

(6) Principal mode of nutrition is photosynthesis but number of plants have become absorptive.

(7) In lower member, organization is protoplasmic or cellular. In higher forms, the organization is of tissue and organ level.

(8) Branches are present. Therefore body form is irregular.

(9) Growth occur due to presence definite growing points or cells. In higher forms, growing areas called meristems.

(10) Locomotion is absent except in some unicellular colonial forms. Multicellular members are sedentary or fixed.

(11) The cells often contain inorganic crystals of different salts.

(12) Vegetative reproduction is quite common.

(13) Asexual reproduction is found in algal group and occur by means of spores.

(14) There is a progressive evolution in sexual reproduction. The reproductive organs are multicellular.

(15) A multicellular embryo is formed during development from the zygote. Algae lack embryo stage. Life cycle consists of alternating haploid gametophyte and diploid sporophyte generation. This phenomenon is called alternation of generation.

### Classification of plantae

August Wilhelm Eichler (1883) a Vinnese botanist, divided plant kingdom into two subkingdoms mainly on the basis of presence or absence of seeds.

(1) **Cryptogamae** (Gr. *Cryptos* = hidden, *gamos* = marriage) : Lower plants in which sex organs are hidden and seeds and flowers absent. It includes **Thallophytes**, **Bryophytes**, **Pteridophytes**.

(2) **Phanerogamae** (Gr. *Phaneros* = visible; *gamos* = marriage) : Higher plants in which sex organs are evident; seeds present. It includes Gymnosperms and Angiosperms.

**Engler** (1886) divided plants into Thallophyta (plant body thallus like and there is no embryo formation) and Embryophyta (zygote develops into multicellular embryo).

**Thallophyta** (Gr. *Thallos* = undifferentiated, *phyton* = plant). This term was coined by Endlicher (1836). It includes Algae, Fungi, Bacteria, Lichens. Unger (1838) placed algae, fungi and lichens under thallophyta. In modern system of classification like Whittaker (1969), Fungi, Lichens and Bacteria are excluded from this group and are placed in separate kingdoms.

### Algae

(Gk. *Phycos* = alga or sea weed)

The branch of botany dealing with the study of algae is called as **phycology** or **algology**. They are simple, thallose, autotrophic non-vascular plants having unicelled sex organs and no embryo formation. In Whittaker's classification, algae are grouped in three kingdom – Monera (blue green algae), Protista (dinoflagellates, diatoms, euglenoids) and Plantae (green algae, red algae and brown algae).

According to Fritsch (**Father of algology**), (1935) the designation alga must include all holophytic organisms, as well as their numerous colourless derivatives, that fail to reach the level of differentiation characteristic of archegoniatae plants.

**Occurrence** : The algae occur in a variety of habitats which are summarised here under

**Fresh water forms** : They occur in rivers, ponds, pools, lakes and ditches. Those forms which remain attached to bottom soil are called as epipelic. Several forms remain attached to bottom or at the bank or to submerged objects. They are described as benthos. Many forms remain attached to rocks or stones. They are described as epilithic or lithophytic. e.g., *Batrachospermum*.

**Marine forms** : Most of the members of brown algae, red algae some green and blue-green algae occur in sea. While some occur as phytoplanktons and benthos, others occur as lithophytes. The giant forms like *Macrocystis* (60 meters) and *Nereocystis* (50 meters) are also marine.

**Terrestrial forms** : Several members of green and blue-green algae and a few others occur on damp soil. While forms like *Oscillatoria* and *Nostoc* occur on alkaline and calcareous soil, *Fritschella* grows on acidic soil. Xanthophyceae members like *Vaucheria* and *Botrydium* growing on damp shady soil or on shady walls, are often described as Saprophytes.

#### Specialized habitats

**Cryophytes** : Plants growing on snow or ice are called as **cryophytes**. Different algal forms produce a specific colour effect while growing as cryophyte e.g., yellow-green by *Chlamydomonas yellowstonensis*, red by *C. nivalis*, black by *Scotella nivalis* and purple-brown by *Ancylonema nordenskioldii*.

**Thermophytes** : Plants growing in hot water are called as **thermophytes**. Some blue-green algae grow in hot water springs at about 70°C e.g., *Oscillatoria brevis*.

**Epiphytes** : Several algal forms grow on other plants (algae, angiosperms) as epiphytes. e.g., *Oedogonium*, *Cladophora*, *Vaucheria* etc.

**Endophytes** : Some blue-green algae grows as endophytes inside other plants e.g., *Anabaena* growing inside the leaf of *Azolla* (fern), *Nostoc* inside the thallus of *Anthoceros* (hornwort) and *Anabaena*, *Nostoc*, *Oscillatoria* inside the coralloid roots of *Cycas*.

**Epizoic** : Algae growing on the bodies of animals are described as epizoic. e.g., *Cladophora crispata* grows on snail shell, *Characium* grows on the antennae of mosquito larvae, *Cyanoderma* (red alga) and *Trichophilus* (green alga) are grows on scales of sloth.

**Endozoic** : Algae growing inside the body of animals. e.g., *Chlorella* grow within the tissue of *Hydra*. Some blue-green algae also grow in the respiratory tract of animals. The blue-green algae which grow endozoically inside the protozoans are called as cyanellae.

**Symbiotic forms** : Some algae like *Chlorella*, *Nostoc* etc. growing in symbiotic relationship with members of Ascomycetes and Basidiomycetes (Fungi) constitute the lichen.

Some species of *Cladophora* live in symbiotic association in a sponge *Ephydatea*.

**Parasites** : The alga *Cephaleuros virescens* grows as a parasite on the tea leaves. In addition, *Rhodochytrium*, *Phyllosiphon* are other parasitic algal forms

*Phyllobium sphagnicolum* is parasite on *Sphagnum* (moss).

#### Thallus organization

The algae show a considerable variation in the organization of the thallus :

(1) **Unicellular forms** : Several members of algae are unicelled. They may be motile (*Chlamydomonas*) or non-motile (diatoms). Some forms have a thick wall and become sedentary for certain duration in their life history. They are called as **coccoid** e.g., *Chlorella*, *Chlorococcus*.

(2) **Multicellular forms** : Multicellular forms are following :

**Colonial** : A colony consists of independent organisms. While the colony of *Volvox* is motile, that of *Hydrodictyon* is fixed. A colony having fixed number of cells and division of labour is called as coenobium e.g., *Volvox*.

**Palmelloid** : Here the vegetative cells of the alga get surrounded by a mucilaginous matrix e.g., *Tetraspora*, *Aphanotheca*.

**Dendroid** : Here the colony appears like a microscopic tree. There is secretion of mucilage from the polar end e.g., *Ectballoclystis*.

**Rhizopodial** : Cells are united through rhizopodia e.g., *Chrysidiastrium*.

**Filamentous** : Most of the algal forms are filamentous. The filaments may be uniseriate or multiseriate, free floating (*Spirogyra*) or attached (*Ulothrix*), unbranched (*Ulothrix*) or branched (*Cladophora*). The branches may be monomorphic (*Cladophora*) or dimorphic (*Batrachospermum*). The branching may be lateral or dichotomous, true (*Ectocarpus*) or false (*Scytonema*). The filaments may be monosiphonous (*Batrachospermum*) or polysiphonous (*Polysiphonia*). In some filamentous forms there is distinction of a prostrate system and an erect system, thus constituting the heterobrichous habit. e.g., *Stigeoclonium*.

**Siphonous** : An aseptate, multinucleate (coenocytic) condition of a filament or thallus constitutes the siphonous habit e.g., *Vaucheria*.

**Parenchymatous** : Parenchymatous organization of the thallus has been observed in many members of brown algae (*Sargassum*, *Laminaria*), red algae (*Gracillaria*, *Porphyra*) and a few green algae (*Chara*, *Ulva*) etc.

#### Cell organization

Most of the algal groups (except blue-green and dinoflagellates) show eukaryotic cell structure. The cell wall is made up of **cellulose**. Some red algae (*Corallina*) have impregnation of  $\text{CaCO}_3$ . The cells possess a well organised nucleus. The minimum chromosome number in algae is  $n = 2$  (*Porphyra linearis*) and the maximum number is  $n = 592$  (*Netrium digitalis*). The cells possess distinct mitochondria, plastids, E.R., ribosomes and golgi body. There may be a single thylakoid in the granum of Rhodophyceae, two in Cryptophyceae, three in Phaeophyceae and Bacillariophyceae but generally many.

The motile forms also possess flagella. They show the usual 9 + 2 structure. They are of two types – **acronematic** (whiplash type) and **pleuronematic** (tinsel type).

**Reproduction**

The algae reproduce vegetatively, asexually and sexually. Various methods involved in reproduction are discussed in the following account.

1) **Vegetative reproduction** : It occurs by following types.

**Fragmentation** : It occurs due to breakage of filament or thallus into fragments, each of which behaves as an independent organism e.g., *Ulothrix*, *Spirogyra* etc.

**Fission** : The unicelled forms like diatoms, desmids multiply by fission i.e., simple cell division.

**Budding** : A bud arises as a papilla on the parent cell. It enlarges and finally separates e.g., *Protosiphon*.

**Akinetes** : Due to deposition of food material followed by thickening of the parent wall, a cell is transformed into an akinete. They may be formed in a chain. On the arrival of favourable conditions, they germinate to form a new plant e.g., *Cladophora*, *Ulothrix*, *Nostoc* etc.

(2) **Asexual reproduction** : It occurs by the formation of various types of spores in sporangia. Except the zoospores, all other types of spores are non-motile.

**Zoospores** : These are thin walled motile spores. They are anteriorly biflagellate and the two flagella are similar in *Cladophora*. In *Vaucheria* and *Ectocarpus* they are laterally biflagellate and the two flagella are dissimilar. Multiflagellate zoospores are formed in *Oedogonium* and *Vaucheria*. In *Vaucheria* the flagella are present all over the surface in pairs and hence it is called as **synzoospore**.

**Aplanospores** : They are thin walled and non-motile spores commonly formed in *Chlamydomonas*, *Ulothrix* etc.

**Autospores** : They are also thin walled, non-motile spores which resemble the parent cell e.g., *Chlorella*.

**Hypnospores** : These are thick walled non-motile spores formed to tide over unfavourable condition. They germinate on the arrival of favourable conditions e.g., *Chlamydomonas*, *Ulothrix*.

**Carpospores** : In red algae, carposporangia are formed at the tip of gonimoblast filaments which produce a single haploid or diploid carpospore e.g., *Batrachospermum*, *Polysiphonia*.

**Tetraspores** : Four non-motile tetraspores are formed inside a tetrasporangium as a result of mitosis in brown algae (e.g., *Dictyota*) or by meiosis in red algae (e.g., *Polysiphonia*).

**Monospore** : The juvenile stage of *Batrachospermum*, a red alga, multiplies by forming a single monospore formed inside a monosporangium.

**Palmella stage** : In dry conditions, zoospores or aplanospores get surrounded by mucilaginous sheath. The divisions continue and they take the shape of colony. This is known as palmella stage. Under favourable conditions each zoospore gives rise to a new plant. e.g., *Chlamydomonas*.

(3) **Sexual reproduction** : The sexual reproduction in algae is broadly of three types as under :

**Isogamy** : It involves fusion of gametes which are morphologically and physiologically similar. They are called as isogametes e.g., *Chlamydomonas eugametos*. In diatoms, there is simplification of isogamous reproduction.

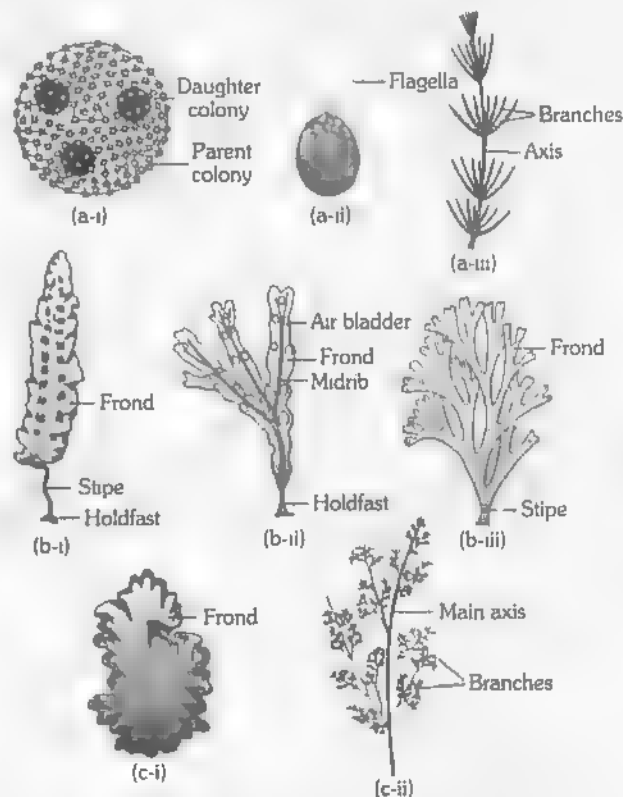
**Anisogamy** : When the two gametes are morphologically dissimilar, the anisogamy is said to be **morphological** e.g., *Chlamydomonas braunii*, *Ectocarpus secundus*. Here the smaller gamete may be called as male and the large one as female. When the two gametes are morphologically similar but differ in their behaviour, the anisogamy is said to be **physiological** e.g., *Spirogyra*, *Ectocarpus siliculosus*.

**Oogamy** : In this process there is formation of unicelled sex organs. The male sex organ is called as antheridium and the female as oogonium. The antheridium forms the male gametes called antherozoids which are generally flagellate. The oogonium forms a non-motile female gamete called egg. The oogamy involves fusion of antherozoids with egg. The simplest type of oogamy is seen in *Chlamydomonas coccifera*.

**Important features of some selected classes**

**Chlorophyceae or Green algae** : Plants are fresh water or marine and forms unicelled to parenchymatous. Chief photosynthetic pigments are chlorophyll a, b;  $\alpha$ ,  $\beta$ ,  $\gamma$ -carotenes, lycopene; lutein, violaxanthin. Reserve food is **starch**. Zoospore are formed and male gametes are flagellate. Flagella identical. Sexual reproduction – Isogamous, anisogamous or oogamous type. e.g., *Chlamydomonas*, *Spirogyra*.

**Xanthophyceae or Yellow green algae** : Plants are generally fresh water and forms unicelled to siphonous. Chief photosynthetic pigments are chlorophyll a, e;  $\beta$ -carotene, violaxanthin, neoxanthin. Reserve food is **chrysolaminarin** and **oils**. Zoospore are formed and male gametes flagellate. Flagella non-identical (unequal). Sexual reproduction – Isogamous, anisogamous or oogamous type. e.g., *Vaucheria*.

**Fig : 1.6-1**

**Algae :** (a) Green algae (i) *Volvox* (ii) *Chlamydomonas* (iii) *Chara*  
(b) Brown algae (i) *Laminaria* (ii) *Fucus* (iii) *Dictyota*  
(c) Red algae (i) *Porphyra* (ii) *Polysiphonia*

**Phaeophyceae or Brown algae :** Plants are marine and forms unicelled to parenchymatous. Chief photosynthetic pigments are chlorophyll a, c;  $\beta$ -carotene, fucoxanthin (brown colour), lutein, violaxanthin, diatoxanthin. Reserve food is **laminarin, mannitol and oils**. Zoospore are formed and male gametes flagellate. Flagella unequal. Sexual reproduction – Isogamous, anisogamous or oogamous type. e.g., *Fucus*, *Dictyota*

**Rhodophyceae or Red algae :** Plants are generally marine and forms filamentous to parenchymatous. Chief photosynthetic pigments are chlorophyll a, d is present but chlorophyll c is absent;  $\alpha$ ,  $\beta$ -carotene, lutein, violaxanthin, fucoxanthin, myxoxanthin,  $\gamma$ -phycoerythrin (red colour),  $\gamma$ -phycocyanin (blue pigment) and allophycocyanin. Reserve food is **floridean starch**, galactan  $-SO_4$  polymers. Zoospores are not formed and male gametes are non-flagellate. Sexual reproduction by specialized type of oogamy. Life cycle haplobiontic or diplobiontic. e.g., *Polysiphonia*, *Porphyra*.

**Myxophyceae or Cyanophyceae :** Plants are generally fresh water, a few forms marine and forms unicelled to filamentous. Cells showing prokaryotic organization. Chief photosynthetic pigments are chlorophyll a;  $\beta$ -carotene; lutein, myxoxanthin, oscillaxanthin, c-phycocyanin, c-phycoerythrin, allophycocyanin. Reserve food is **cyanophycean starch (glycogen)** and cyanophycin (protein). Zoospore are not formed and no flagellate bodies. Sexual reproduction is absent. e.g., *Nostoc*, *Anabaena*.

#### Economic importance

##### Useful aspects

**Nitrogen fixation :** Some fifty species of blue-green algae are capable of fixing atmospheric nitrogen in the soil e.g., *Anabaena*, *Aulosira*, *Cylindrospermum*, *Nostoc* and *Tolypothrix* etc. Under aerobic conditions, nitrogen is fixed by heterocysts only. Under anaerobic condition the vegetative cells also show nitrogenase activity.

**Algae as food :** Many green algae such as *Chlorella*, *Ulva*, *Caulerpa*, *Enteromorpha*, etc. are used as food. *Chlorella* has about 50% protein and 20% of lipid and carbohydrates. The *Chlorella* protein contains all the amino acids essential for human nutrition. *Ulva lactuca* has formerly used in salad and soup in Scotland.

**Green algae in space research :** In recent years biologists have realized that unicellular green algae (e.g., *Chlorella*) could be used to provide  $O_2$  during space flight trips.

**Antibiotics :** The genus *Chlorella* yields an antibiotic **chlorellin**, which is used against Gram +ve and Gram -ve bacteria, especially *Escherichia coli*, *Shigella dysenteriae* and *Staphylococcus aureus*. The genus *Caulerpa* also yields antibiotics.

**Alginates :** Alginic acid is a polymer of carbohydrate. It occurs in the cell wall and middle lamella. They are obtained from *Laminaria*, *Ascophyllum*, *Fucus*, *Nereocystis*, *Turbinaria* etc. They are used in pharmaceuticals as emulsifiers and stabilizers as well as for making pills, antibiotic capsules etc. They are also used in the preparation of soups, jellies, cosmetics, toothpastes, polishes, hair dyes, compact powders, lotions, shampoos etc.

**Carrageenin :** It is a polysaccharide colloid (phycocolloid) obtained from the red algae *Chondrus crispus* and *Gigartina stellata*. It is widely used in soups, sauces, milk shakes, cheese, jellies, cream and fruit juices. It is also used in painting and printing.

**Agar-agar :** It is a non-nitrogenous carbohydrate consisting of two polysaccharides namely agarose and agarpectin. It is obtained from several red algae e.g., *Gracilaria*, *Gelidium*, *Gigartina* and *Chondrus* etc. It is insoluble in cold water but soluble in hot. It is used as a base for a variety of culture media.

**Source of minerals and elements :** The members of brown algae called '**kelps**' have been the source for obtaining iodine e.g., *Laminaria*, *Macrocystis*, *Fucus*. About 25% of total iodine is extracted from kelps. Similarly red algae like *Rhodomela*, *Polysiphonia* and *Rhodymenia* are sources of bromine.

**Sewage disposal :** Green unicellular algae such as *Chlorella* and *Chlamydomonas* are used in sewage disposal ponds. They remove  $CO_2$  and restore  $O_2$  by the process of photosynthesis.

**Medicines :** Sodium laminin sulphate are used as blood anticoagulant and obtained from *Laminaria* and *Durluilla* has antiworm (vermifuge) properties.

**Source of protein :** The protein of *Chlorella* is superior to cereals as it contains all essential amino acids. Its nutritional value is equal to soybean and spinach.

##### Harmful aspects

**Algal toxicity :** Some dinoflagellates like *Prymnesium*, *Gymnodinium* are extremely poisonous to fishes. The blue-green alga *Microcystis* secretes hydroxylamine which not only kills aquatic life but also the birds and cattle who care to drink water. While *Lyngbya* and *Chlorella* may cause skin allergies in human beings.

**Algal parasitism :** The red alga *Cephaleuros virescens* causes red rust of tea thus destroying the tea leaves. Similar disease are caused by the species of *Cephaleuros* to coffee plant, *Piper* and *Citrus* sp.

**Spoilage of drinking water :** Forms like *Anabaena*, *Microcystis* not only spoil the taste of drinking water but also produces toxic effect. The growth of algae is controlled by using **algicides** such as dichlorophen, sodium perborate, phygon XI, exalgae, delrad etc.

**Water blooms :** Algae grow abundantly in water reservoirs where excess of nutrients are available to them. This algal growth floats on the water surface and look like foam or soap lather. It is called water bloom. e.g., *Microcystis*, *Anabaena*, *Oscillatoria* etc.

#### Some representative algae

##### *Spirogyra*

##### Habitat

*Spirogyra* was discovered by Link. It is an unbranched filamentous green alga of stagnant fresh waters which forms floating masses (supported by bubbles of oxygen) called **pond scum**. A sheath of mucilage occurs on the outside. It gives a silky touch. Hence *Spirogyra* is also called **water silk** or **mermaid's tresses**.

##### Structure

The thallus is an unbranched and uniseriate filament where cells are arranged in a single row. In some species hold fast is present (e.g., *S. fluviatilis*). The cells are elongated and cylindrical. The cell wall is two layered the outer is of pectic substance and the inner of cellulose. The outer part (pectin) dissolves in water to form a mucilaginous sheath

Due to this reason *Spirogyra* filaments are slippery. Transverse or septum can be plane, colligate (with H-shaped piece), replicate (ring like ingrowths) and unduliseptate (undulate). The protoplast is differentiated into plasma membrane, thin layer of cytoplasm, single nucleus, one (e.g. *S. sahnii* and *S. venkataramanni*) or many (16 in *S. rectisporea*) ribbon (spiral) shaped chloroplasts (wavy margin) with pyrenoids and a large central vacuole. Pyrenoid is made of protein surrounded by starch plate or starch grains and it is the centre of starch formation. Nucleus occurs inside the central vacuole where it is suspended by means of cytoplasmic strands.

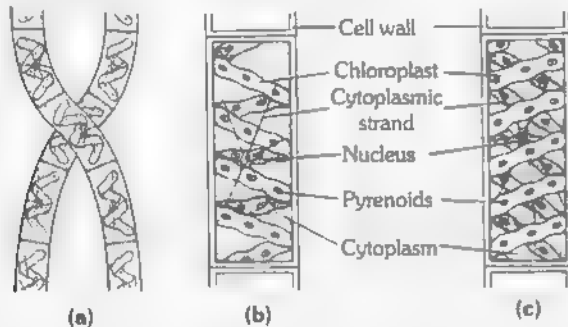


Fig : 1.6-2 *Spirogyra* (a) Two filaments (b) and (c) Detailed structure of a cell

### Reproduction

*Spirogyra* reproduces by vegetative, asexual and sexual methods.

(1) **Vegetative reproduction** : It takes place by fragmentation of filament. Later on, each segment gives rise to new plant.

(2) **Asexual reproduction** : Normally asexual reproduction is absent in *Spirogyra*. It occurs only occasionally by the formation of akinetes, aplanospores and azygospores (Parthenospores).

**Akinetes** : Under unfavourable conditions, the cells of the filament develop into thick walled structures, which are known as akinetes. On the onset of favourable conditions, these give rise to new plants. Their wall is made up of cellulose and pectin e.g., *S. farlowii*.

**Aplanospores** : These nonmotile aplanospores are either round or oval. These later on under favourable condition give rise to the new individuals. Aplanospores are known to occur in *S. aplanosporea*, *S. articulata* etc.

**Azygospores or Parthenospores** : If there is sudden change in the environment, the gametes fail to fuse and each functions as parthenospore.

(3) **Sexual reproduction** : The sexual reproduction in *Spirogyra* is called conjugation. It involves the fusion of two morphologically identical, but physiologically dissimilar gametes.

#### The conjugation is of two types

(1) **Scalariform conjugation** : This is the most common and advanced type of conjugation. It involves two filaments of *Spirogyra* and takes place between two recently formed cells. The cells of one filament show the formation of papilla towards the other filament.

It stimulates the formation of similar papilla in cells lying opposite to them. The two papillae fuse by enzymatic dissolution of the wall thus forming a conjugation canal.

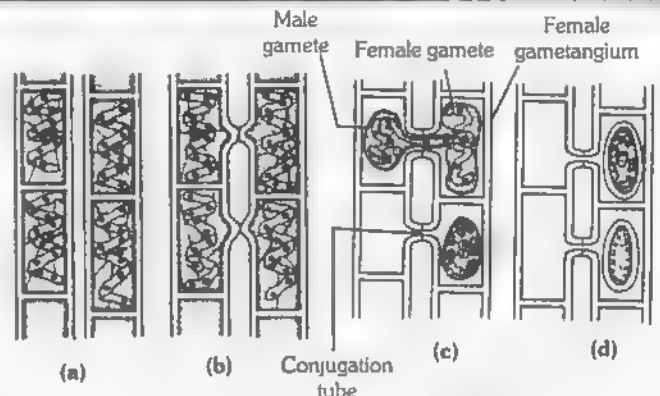


Fig : 1.6-3 (a)-(d) Sexual reproduction showing scalariform conjugation in *Spirogyra*

The conjugation tube between the two filaments looks like a ladder, through which gamete from one of the gametangia passes through to fuse with the passive gamete of another filament. The gametes are formed singly and both **active** and **passive** gametes are considered male and female gametes respectively. The fusion of both kinds of gametes with each other results into formation of zygospore.

The zygospore wall is differentiated into three layers, the outer **exospore** which is thin, the middle **mesospore** which is a thick layer of cellulose, chitinized and pale yellow to brown in colour, and inner **endospore** which is thin and cellulose in nature.

(2) **Lateral conjugation** : It takes place between two nearest cells of the same filament (homothallic). Both male and female gametes are found in same filament. It is of two types.

(i) **Indirect lateral conjugation** : Two outgrowths appear on both sides of a transverse septum of two adjacent cells which later on form a conjugation tube. Of the two cells, one behaves as male gametangium from which gamete passes through the tube into female gametangium. By fusion, zygospore is formed. Thus in each second cell of a filament zygospore is formed. It is commonly seen in *S. affinis* and *S. tenuissima*.

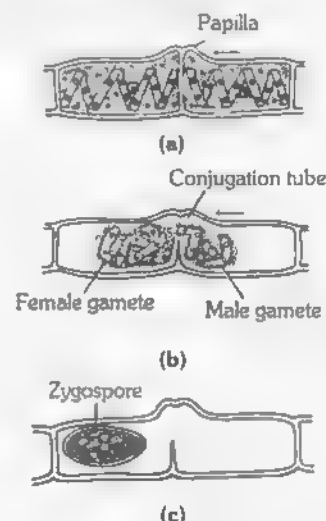


Fig : 1.6-4 Sexual reproduction showing lateral (indirect) conjugation in *Spirogyra*

(ii) **Direct lateral conjugation** : In this type of conjugation, the male gamete after passing through an aperture in the transverse septum of adjoining gametangium enters the female

gametangium and fuses to form a **zygospore**. The two gametes, though morphologically alike but differ in their behaviour. Hence this type of sexual reproduction corresponds physiologically anisogamy. It is commonly seen in *S. jogensis*.

**Germination of zygospores :** The zygospores on the arrival of favourable conditions germinate. The nucleus undergoes meiosis to form four haploid nuclei (tetra nucleate). Of these three nuclei degenerate and one functions.

The exo and mesospores rupture and the endospore protudes out in the form of germling. The new cell undergoes transverse division continuously to form a new filament. Thus in the life cycle of *Spirogyra*, there is no flagellate phase.

Life cycle in *Spirogyra* is **haplontic** as dominant phase in life cycle is haploid ( $n$ ) and diploid phase is represented by only zygospore and it undergoes R.D. or meiosis (zygotic meiosis).

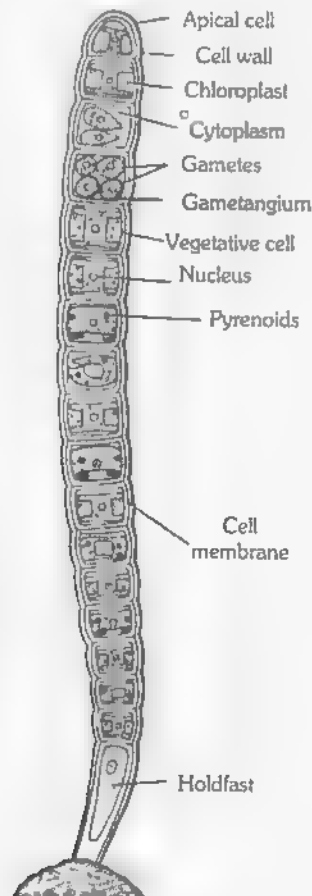
### ***Ulothrix***

#### **Habitat**

It is a green filamentous algae found in slow running fresh water streams. The common species *U. zonata* occurs in cold water whereas *U. flacca* is marine. *U. implexa* occurs in estuaries (where river meets the sea) as **lithophytes**.

#### **Structure**

An unbranched filament, consisting of numerous cylindrical or rectangular cells joined end to end. The filaments remain attached to some substratum by means of rhizoidal cell, i.e., showing distinction in base and apex. The basal cell is elongated and colourless known as holdfast while the uppermost cell is rounded.



**Fig : 1.6-5 A vegetative filament**

Cell wall consists of two layers. Inner layer is made up of **cellulose** and outer layer is mostly made up of **protopectin** which is insoluble in water.

Due to presence of protopectin, *Ulothrix* filaments appear as **wet threads**. In the centre of the cell is a nucleus and single **girdle** or **ring** shaped (*U. zonata*) or collar shaped chloroplast. One (*U. rorida*) or more pyrenoids are present in the chloroplast. A vacuole is present, surrounding it is a thin layer of cytoplasm (primordial utricle).

#### **Reproduction**

The *Ulothrix* reproduces vegetatively, asexually as well as sexually.

(1) **Vegetative reproduction :** It takes place by fragmentation. In this process a filament divides into small parts. These smaller fragments grow and give rise to new filaments of *Ulothrix*.

(2) **Asexual reproduction :** It takes place by the production of zoospores, aplanospores, hypnospores, akinetes and palmella stage.

**Zoospore formation :** In favourable conditions, each cell produces zoospores except holdfast. Cytoplasm collects in the centre and divides into 2,4,8,16 or sometimes 32 segments. Each segment develops into biflagellate or quadriflagellate zoospores. Each zoospore is uninucleate, pear-shaped with thin cell membrane (zoospores not having cell wall). The zoospores are of 3 types :

**Quadriflagellate macrozoospores :** Usually 4 per cell.

**Quadriflagellate microzoospores :** Usually 8 per cell.

**Biflagellate microzoospores :** Usually 16-32 per cell.

The zoospores come out into a vesicle, later on the wall disintegrates (forming a pore in lateral wall) and macro and microzoospores are liberated free and float in water. Microzoospores attach to substrate by their anterior ends while macrozoospores attach by their posterior ends. After sometime zoospores give rise to new individuals.

In *Ulothrix*, aplanospores, hypnospores and akinetes are also formed under unfavourable conditions.

**Palmella stage :** It is produced in water deficiency or presence of toxic chemicals. A number of small green naked cells are formed in mucilage sheath. These cells can grow and divide. On the approach of favourable condition each cell now change into a quadriflagellate zoospore. Zoospore develop into new plants.

(3) **Sexual reproduction :** It occurs at the end of growing season. *Ulothrix* is heterothallic. Sexual reproduction is of isogamous type. The gametes are motile and biflagellate. Except holdfast each cell of the filament can give rise to 64 to 128 gametes.

These gametes are smaller than zoospores. On dehiscence of gametangium, the gametes come out in a bag like structure and float on water.

When two gametes of (+) and (-) strain come together, they fuse and a quadriflagellate zygospore is formed which after floating for sometime on water, rests on the bottom of the pond. At this time, its four flagella disintegrate and a wall is formed surrounding it from all sides. After taking a rest for long period it divides meiotically and gives rise to 4-16 aplanospores or zoospores. These come out of the sac and give rise to a new plant of *Ulothrix*.



## Bryophyta

(Gk. *Bryon* = moss; *phyton* = plants)

Bryophyta includes the simplest and primitive land plants. Which are characterised by the persence of independent gametophyte and parasitic sporophyte. The term bryophyta was coined by Braun (1864) but bryophytes were delimited in its present form by Schimper (1879). It occupies a position intermediate between algae and pteridophyta. Due to peculiar type of their habitats, they are regarded as 'the amphibians of the plant kingdom'. The science connected with the study of bryophytes called bryology

### Habitats

Bryophytes usually grow in moist and shady places. The plants grow densely together and form green carpets or mats on damp soil, rock, walls, barks of trees and on decaying logs in forests, especially during the rainy season.

**Specialized habitats :** Some bryophytes grow in diverse habitats such as – **aquatic** (e.g., *Riccia fluitans*, *Ricciocarpus natans*, *Pellia*), **epiphytes** (e.g., *Dendroceros*, *Radula protensa* and many mosses), **saprophytes** (e.g., *Buxbaumia aphylla*, *Cryptothallus mirabilis*), and in **dry habitats** such as dry heaths (e.g., *Polytrichum juniperinum*), deserts (e.g., *Tortula desertorum*) and dry rocks (e.g., *Porella platyphylia*).

### Gametophytic plant body

(1) The life cycle of bryophytes consists of two distinct phases – the gametophytic phase and the sporophytic phase. The haploid gametophyte is dominant, long lived, green and independent whereas the diploid sporophyte is short lived and dependent upon the gametophyte. The two phases are morphologically distinct.

(2) The plants are small, range from few millimetres (e.g., *Zoopsis*) to 30–40 centimetres. The tallest species may reach upto 70 cm in length (e.g., *Dawsonia*).

(3) The gametophytes are either thalloid (i.e., not differentiated into true roots, true stem and true leaves) or leafy shoot having stem-like central axis and leaf-like appendages.

(4) The roots are completely absent and they are replaced by unicellular or multicellular thread like rhizoids. In some higher forms the multicellular rhizoids form cords.

(5) The vascular tissue (i.e., xylem and phloem) are completely absent.

### Reproduction

(1) **Vegetative reproduction :** The bryophytes reproduce vegetatively by following methods .

**Death and Decay :** Most of these plants reproduce vegetatively by gradual death and decay of the older part of the plant body.

**Adventitious branches :** Many plants like *Riccia fluitans*, *Reboulia*, *Asterella*, *Pellia* etc. reproduce by adventitious branches. They separate and produce new plants.

**Tubers :** Several species of *Riccia*, *Anthoceros*, *Sewardiella*, *Asterella* etc. produce tubers which give rise to new plants on the arrival of favourable conditions.

**Gemmae :** Several members, reproduce vegetatively by forming multicelled gemmae. In *Marchantia*, *Lunularia*, the gemmae are produced in **gemma cups**. Gemmae are also produced on the thallus of *Anthoceros*. Several mosses also produce gemmae on the 'leaves' (*Bryum*), or axis or rhizoids or on the protonema (*Funaria*).

**Primary protonema :** The mosses generally reproduce vegetatively by breaking of the primary protonema. New gametophores now arise from the buds differentiated on it.

**Secondary protonema :** In several mosses a secondary protonema may arise from the rhizoids or primary protonema or even from the injured sporophyte. It may produce buds which give rise to new gametophores.

**Rhizoids :** Mosses may also reproduce vegetatively from the rhizoids e.g., *Leucobryum*.

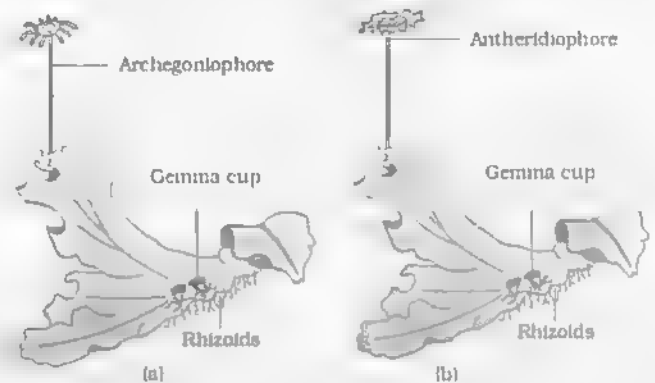


Fig : 1.6-6 Bryophytes (a) Female Thallus (b) Male Thallus

(2) **Sexual reproduction :** It is oogamous, between a flagellate sperm or antherozoid and non motile egg or oosphere. The male sex organs is called as antheridium and the female as archegonium. The antheridial stalk is very distinct whereas the archegonial stalk is generally short. They may be of embedded type e.g., *Riccia*, *Anthoceros* or of projecting type e.g., *Marchantia*, mosses.

**Antheridia :** They are generally borne on the dorsal surface of the thallus. Each antheridium is distinguishable into a stalk and the body. The antheridial body consists of a mass of androgonial cells covered by a 1-cell thick sterile jacket. The terminal cell of the jacket, when distinct, is called as **operculum**. Each androgonial cell finally behaves as androcyte mother cell. The androcyte mother cell then forms two androcytes (antherozoid mother cell), each of which is metamorphosed into a biflagellate antherozoid.

**Archegonia :** These are also borne on the dorsal surface of the thallus. The archegonia are **flask shaped** structures distinguishable into a long neck and a globular, swollen venter. A multicelled stalk is also present in mosses but in others it is very short. The neck is one-cell thick. It is generally made up of six vertical rows of cells. The neck is capped by four cover cells and contain varying number of neck canal cells inside. The venter is also 1-cell thick in most of the plant. The venter contains an egg and a ventral canal cell.

### Importance of water in fertilization

The bryophytes are fundamentally terrestrial plants but require presence of water to complete their life cycle. The water is needed for dehiscence of antheridia, liberation of antherozoids, transfer of antherozoids from antheridia to archegonia, opening of archegonial neck, and the movement of antherozoids into the archegonial neck.

Before fertilization the walls of androgonial cells disorganise to form a mucilaginous mass. The opercular cell is removed and the antherozoids are liberated. The neck canal cells and the ventral canal cell also disorganise. The cover cells split apart giving a free passage to incoming antherozoids. The antherozoids are attracted towards the egg by chemotactic stimulus, which in bryophytes, is provided in the form of sugars. Antherozoids enter into archegonia and fertilized the egg.

#### Sporophyte

(1) The diploid fertilized egg (zygote) is the first cell of sporophytic generation. It divides and develops into a sporophytic plant body called sporogonium.

(2) The wall of venter forms calyptra, which provides a protective covering to the developing sporogonium.

(3) The sporogonium, in most of the cases, is differentiated into foot, seta and capsule.

(4) The sporogonium is completely dependent on the gametophyte for water and mineral supply and, in most of the cases, partly or wholly for organic nutrition. The sporogonium remains attached to the gametophytic plant body throughout its life.

(5) The sporogonium is mainly concerned with the production of asexually formed haploid spores (or meiospores). The spores are produced inside the capsule of sporogonia as a result of meiosis in the spore mother cells.

(6) The spores are the first cells of gametophytic generation. They germinate to produce the gametophytic plant body either directly or through a juvenile filamentous stage, called protonema.

#### Important features of classes

Campbell (1940), Smith (1955), Takhtajan (1953) divided bryophyta into three classes namely **Hepaticae**, **Anthocerotae** and **Musci**. Proskauer (1957) changed the names of these classes in accordance with the recommendations of the code, into **Hepaticopsida**, **Anthocerotopsida** and **Bryopsida**.

**Hepaticopsida** : The latin word Hepatica means liver. Thus the members of hepaticopsida are popularly known as **liverworts**.

The gametophytic plant body is small, dorsiventral, thallose or leaf axis (foliose). Chlorophyllous cells contain many chloroplasts, one to several oil bodies, pyrenoids are absent. Rhizoids are unicellular. Sex organs develop from single superficial cells.

**Anthocerotopsida** : Gametophyte is thalloid. Thalli are lobed, dorsiventral, internally homogenous without any differentiation of tissues. Air chambers and air pores are absent but mucilage cavities may be present. Rhizoids are only smooth walled and scales are absent. Each cell possesses single (some times more) large chloroplast with central pyrenoid and oil bodies are absent. Antheridia are endogenous in origin, borne singly or in groups inside the closed cavities.

**Bryopsida** : The members of bryopsida are commonly known as **mosses**. Gametophyte is differentiated into two stages – prostrate protonema and erect radial leafy shoot. Leaf-like appendages are spirally arranged on stem like axis. Rhizoids are

multicellular with oblique septa. Sex organs develop from superficial cells.

#### Economic importance

(1) **Soil conservation** : Mosses grow in dense mats over the soil surface. They bind the soil particles and prevent soil erosion by running water.

(2) **Formation of soil** : Mosses along with lichens play a very important role in the formation of soil over the bare rocky surface. They grow on rocks and add organic matter to the substratum after their death. It makes the rock surface suitable for the growth of higher plants.

(3) **Use in nursery** : The *Sphagnum* plants have magnificent property of retaining water. They can hold water two hundred times more than their own weight. Hence they are widely used by gardeners to keep cut plant parts moist during transportation and propagation.

(4) **Peat** : *Sphagnum* plants grow as semiaquatic or submerged in acidic marshes. The older portions of plants die but do not decay due to peculiar germicidal properties. Constantly increasing mass of dead remains accumulate year after year. These dead remains are slowly compressed and become hardened due to weight and forms a compact dark coloured peat rich in carbon.

(5) **Other uses** : Certain bryophytes are used to obtain a number of **antibiotic** substances. Some bryophytes have important medicinal uses. For example – The tea prepared from *Polytrichum commune* is used to dissolve kidney and gall bladder stones.

#### Some representative bryophytes

##### *Funaria* (Moss)

#### Habitat

*Funaria* is known as **common moss** or **green moss** or **cord moss**. There are 117 species of *Funaria* which are worldwide or cosmopolitan in distribution. 25 species have been reported from India. Most common species are *Funaria hygrometrica*, *F. obtusa*, *F. attentua* and *F. fascicularis*.

*Funaria* grows well in recently burnt grounds rich in plant ashes (alkaline condition). Common places for its growth are moist rocks, moist walls and moist grounds.

**External structure (Gametophytic phase)** : The main plant body of *Funaria* is gametophyte and is of two forms.

(1) Juvenile form (creeping protonema).

(2) Adult form (leafy gametophore).

Protonema is the branched filamentous portion which is produced by germination of spores. It is ephemeral or short lived.

**Leaves** : These are small, sessile, ovate with acute apex and broad base. Leaves are arranged spirally in 1/3 phyllotaxy in upper region and 3/8 in lower region. A distinct midrib is present.

On the lower portion of the leafy gametophore, there are presence of branched, multicellular rhizoids with oblique septa.

Initially the rhizoids are colourless and hyaline but at maturity they become dark in colour due to dark cell walls. If rhizoids are exposed to light they become green.

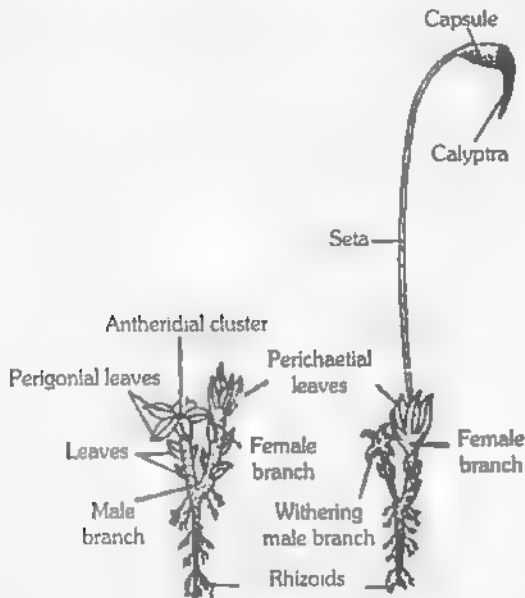


Fig : 1.6-7 *Funaria* plant showing male and female branches

### Reproduction

*Funaria* reproduces both by vegetative and sexual methods.

(1) **Vegetative reproduction** : Vegetative reproduction takes place by fragmentation, primary protonema, secondary protonema, bulbils, gemma and apospory.

In apospory some cells from any part of sporophyte separate from the parent, fall on the soil and form a protonema. Buds of leafy gametophore are produced on the protonema and give rise to a gametophyte-like plant but the cells have diploid set of chromosome ( $2n$ ). In this way a gametophyte like plant is produced from diploid sporophyte without reduction division.

(2) **Sexual reproduction** : The *Funaria* plants are monoecious and autoecious, i.e., male (antheridia, club shaped) and female (archegonia, flask shaped) reproductive organs are produced on the same plant but on different branches. Male organs mature first and hence *Funaria* plants are **Protandrous**.

**Antheridium** : Each male sex organ is reddish brown/orange stalked multicellular club shaped called antheridium. Main branch is male branch which is called antheridiophore. The antheridia are borne at the tip of antheridiophore. The antheridial cluster remains surrounded by a rosette of leaves called Perigonium. In between antheridia are present club shaped green multicelled sterile hair called paraphyses. An antheridium is distinguishable into stalk and the body. It has a 1-cell thick jacket. Jacket is green in the young antheridium but colour changes in mature antheridium. A number of biflagellate sperms are produced by antheridium.

**Archegonium** : Female receptacle appear bud like. It contains a number of archegonia intermixed with pointed 4-5

celled green paraphyses. The whole complex is surrounded by upwardly bending or convergent perichaetial leaves.

The archegonium of moss is distinguishable into a stalk, venter and a neck. The venter is double layered and contains an egg and a ventral canal cell inside. The neck is several cells high and is made up of six vertical rows of cells. It contains six or more neck canal cells. It is capped by four cover cells or lid cells. At maturity the venter canal cell and neck canal cells degenerate to form mucilaginous mass. It absorbs water and swells up and opens the lid to create a passage upto oosphere. Oosphere secretes sucrose for attracting sperms.

**Fertilization** : The neck canal cells and the ventral canal cell also degenerate and the cover cells split apart giving a free passage to incoming antherozoid. The fertilization is affected by water medium. Out of many antherozoids, only one of them is able to fuse with the single egg to produce zygote ( $2n$ ). The zygote without any resting period enlarges and divides to form sporophyte or sporogonium. The first division in zygote is transverse. The epibasal (upper) portion forms capsule and upper half of seta while hypobasal (lower) portion forms foot and lower half of seta.

**Sporophytic phase** : Fully developed sporophyte or sporogonium is made of three regions, i.e., **basal foot, seta and capsule**. Sporophyte is semiparasite on moss plant taking water, minerals and some growth factors.

(1) **Basal foot** : Basal foot is embedded in the apex of female branch and is conical in shape. Its function is to absorb nutrients and to provide support for sporophyte.

(2) **Seta** : It is a long, slender, reddish brown stalk like structure which bears capsule at the top. Internally it is differentiated into a central cylinder and epidermis. The central cylinder helps in the conduction of water and the thick walled cells of the cortex provide mechanical strength to the slender seta.

(3) **Capsule** : Capsule is the terminal pear shaped portion. Initially it is surrounded by calyptra but later on this calyptra breaks up. Stomata are present on the lower part of capsule. The capsule consists of three portions, i.e., basal apophysis, central theca and terminal operculum.

**Apophysis** : Apophysis is green, photosynthetic basal sterile portion of capsule in continuation with seta. In capsule of *Funaria* primitive types of stomata are present only in apophysis

**Theca** : Theca is the fertile middle zone of capsule, situated between apophysis and operculum. The outer layer of theca is epidermis, inner to which is 2 layered hypodermis. Central sterile portion of theca is called columella, outer to which is spore sac containing spores. Spore sac develops from endothecium. It enclose spore mother cells which undergo meiosis to form haploid spores.

Outer to spore sac there are present air spaces transversed by many portions of assimilatory cells called **trabeculae**.

**Operculum** : The upper region of capsule is slightly oblique having upper cap-like portion called operculum. Which covers the peristome. The opercular region is separated from the theca region by two rings. The lower ring is the rim or diaphragm and the upper is annulus. The peristome is distinguishable into two whorls of radially arranged **peristomial teeth**. In each whorl, there are sixteen teeth. Each tooth is a triangular structure. Outer ring of these teeth called exostome (hygroscopic in nature) and inner ring is called endostome (non-hygroscopic in nature).

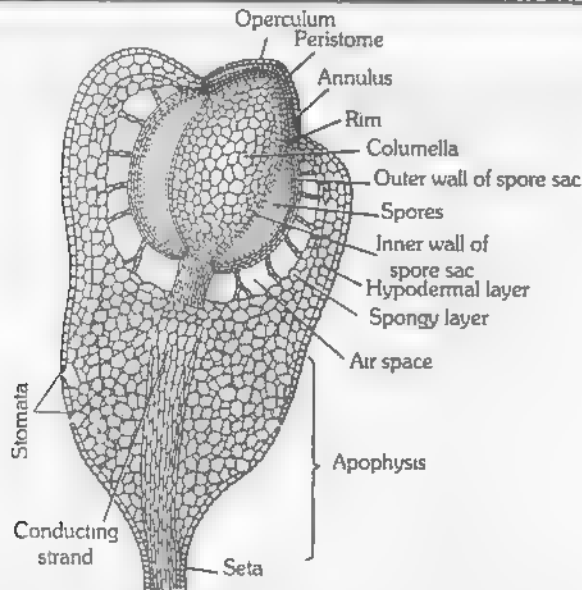


Fig : 1.6-8 L.S. of capsule

**Dehiscence of capsule :** The capsule swings in air due to twisting movements of long seta. As the capsule matures the thin walled cells including columella dry up. The thin walled cells of operculum break away. The operculum is thus separated along the annulus exposing the peristome. The hygroscopic action of the peristomial teeth also help in the removal of operculum. The capsule becomes inverted due to epinasty. It also shows hygroscopic action. The lengthening and shortening of peristomial teeth help in the dispersal of spores. The inner peristome acts as a sieve allowing only a few spores to escape at a time. Spores have a long viability, i.e., 8-15 years.

**Germination of spores :** The spore is the first cell of gametophytic generation. Each spore is spherical with two walls, outer one is smooth and coloured called exosporium and inner colourless smooth endosporium. Inside the spore is a single haploid nucleus, numerous chloroplasts and oil globules.

On approach of favourable conditions the spore absorbs water, outer thick exine ruptures and intine comes out in the form of a germ tube which is cut off by means of a septum (oblique). Then it divides and enlarges to form a branched alga like, filamentous, primary protonema.

There are two generations in life cycle of *Funaria*, i.e., gametophytic generation ( $n$ ) which is independent and complex and sporophytic generation ( $2n$ ) which is partially dependent upon gametophytic generation. These two generations follow each other in regular sequence. This is called heteromorphic or heterologous alternation of generations.

### *Riccia*

#### Habitat

It is a cosmopolitan genus. The plants occur on moist soil or rocks. Most of the species are terrestrial (on damp soils) except *Riccia fluitans*, which is aquatic in nature.

**External structure (Gametophytic phase) :** The main plant body of *Riccia* is gametophytic ( $n$ ). It is small, green, flat and fleshy. The thallus is dorsiventral and dichotomously branched. The thalli are present in the form of patches called **rosettes**. Scales are found on the margins, while rhizoids are present in the mid-rib

region of thallus. Rhizoids are unicellular and unbranched and are of two types – smooth and tuberculate. Rhizoids help in fixation. In submerged species, (e.g., *R. fluitans*) scales and rhizoids are not present.

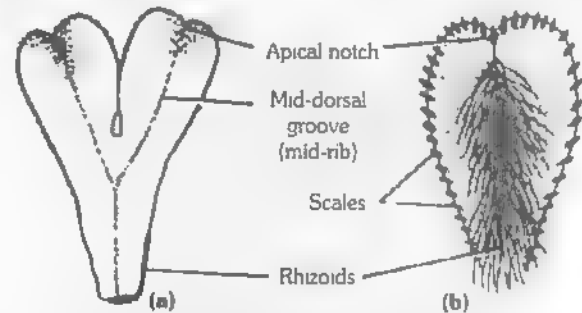
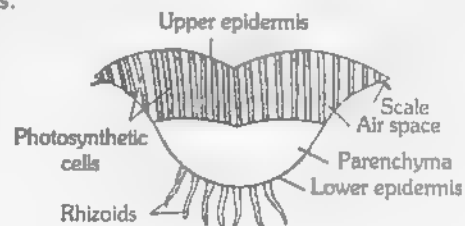


Fig : 1.6-9 Rosette habit (a) Dorsal view of thallus (b) Ventral view of thallus

**Internal structure :** The thallus is internally differentiated into :

**An upper or dorsal photosynthetic region :** It consists of vertical rows of chlorenchymatous cells. In between these vertical rows are present very narrow air canals or air chambers. The canals communicate with the outside through air pores. The uppermost cell of each row is enlarged and non-green. These non green cells of vertical rows form a discontinuous and poorly-defined upper epidermis.

**A lower or ventral storage region :** The lower portion consists of closely packed parenchymatous cells without intercellular spaces. The cells do not contain chloroplasts. They store water and food. The lowermost row of cells form the lower epidermis. Rhizoids and scales develop from the lower epidermis.

Fig : 1.6-10 A V.T.S of *Riccia* thallus

#### Reproduction

*Riccia* reproduces by both vegetative and sexual method.

(1) **Vegetative reproduction :** *Riccia* reproduces vegetatively by progressive death and decay, persistent apices (*R. discolor*), adventitious branches (*R. fluitans*), tubers (*R. billardieri*, *R. discolor*, *R. perennis*) and by rhizoid (*R. glauca*).

(2) **Sexual reproduction :** Sexual reproduction is oogamous type in *Riccia*. Antheridia and archegonia are the male and female sex organs respectively. Sex organs are embedded in the thallus.

**Antheridia** produce biflagellated elongated curved sperms, both flagella are alike (whiplash type). Archegonia are flask shaped with neck and venter. Neck enclose 4-6 neck canal cells. Venter wall is single layered and encloses one venter canal cell and one egg cell (oosphere). It attracts sperm by secreting protein and  $K^+$  salts (chemotaxis).

**Fertilization :** The fertilization is affected by water medium (zooidogamous). Many antherozoids may enter into the archegonium, but only one of them is able to fuse with single egg to form zygote ( $2n$ ), which is beginning of sporophytic phase.

**Sporophytic phase :** Sporophyte or sporogonium is also embedded. It is covered by two layered calyptra. Sporogonium is undifferentiated and function like a spore sac on capsule. Nurse cell wall of sporophyte and inner layer of calyptra degenerate to provide nourishment to growing spores. Mature spores are liberated when the surrounding cells decay or dry up.

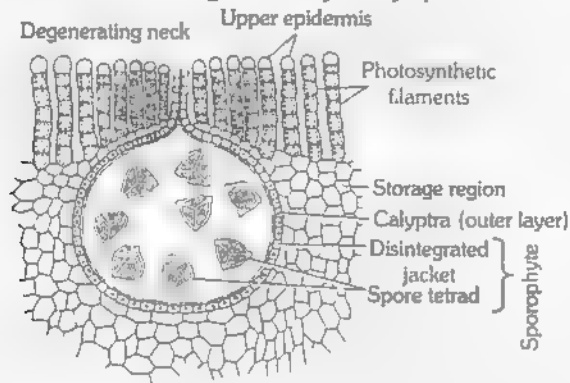


Fig : 1.6-11 V.T.S. of *Riccia* thallus showing mature sporophyte

**Germination of spores :** Spores are the first cells of the next gametophytic generation. Spores are dispersed by the decay of the surrounding thallus tissue. The wall of the spore is thick and sculptured, and is differentiated into three layers- the outer exosporium, the middle mesosporium and the inner endosporium which is made of pectose and callose. The surface is having clear triradiate mark. In the mass of cytoplasm, stored food is present in the form of oil - globules. After liberation, the spores germinate in about 6-10 days in presence of light, low temperature and sufficient moisture contents. After absorbing water, the spore swells up. The endosporium grows out in the form of a germ tube which, after further divisions, develops into a new thallus (gametophyte).

Thus there are 2 generations in life cycle of *Riccia*. The main plant body is gametophytic ( $n$ ). The gametophytic phase starts with formation of spores and ends with fertilization. The second phase is sporophytic phase ( $2n$ ), which starts with zygote and ends with reduction division of spore mother cell. The sporophytic phase is dependent upon gametophyte. Thus there is heteromorphic or heterologous alternation of generations in *Riccia*. So life cycle in *Riccia* is diplohaplontic.

## Pteridophyta

(Gk. *Pteron* = father/fern; *phyton* = plants)

The term pteridophyta was first introduced by Haeckel in (1866). The pteridophytes are flowerless, seedless, spore producing vascular plant which have successfully invaded the land. Pteridophytes represent an intermediate position between bryophytes and spermatophytes (Gymnosperm and Angiosperm). They are also called vascular cryptogams. (The term cryptogams was coined by Linnaeus (1737) which means plants without seeds). The group has a long fossil history. Pteridophytes flourished well during devonian, missipian and pensylvanian periods of late paleozoic age. This period can be well recognised as "age of pteridophyta".

### Habitat

The plants of pteridophytes are mostly terrestrial. They prefer shady habitats. Some species of *Selaginella* and *Adiantum* are xerophytes. A fern, *Acrostichum aureum* is a halophyte. Some species e.g., *Selaginella oregana*, *Psilotum flacidum*, *Lycopodium squarrosum* and ferns like *Asplenium nidus*, *Pleopeltis* sp. are

epiphytes. *Marsilea* occurs as a terrestrial, amphibious as well as an aquatic plant. There are true aquatic ferns like *Salvinia* (*Salvinia* is root less pteridophyte), *Azolla* and *Ceratopteris*

### Sporophytic plant body

(1) The main independent plant body of pteridophytes is sporophyte. It is differentiated into true roots, true stem and true leaves.

(2) The primary root is short lived. It is replaced by adventitious roots. The root has a permanent growing apex.

(3) The stems are usually herbaceous (except in some woody ferns) and branched monopodially or dichotomously.

(4) The leaves may be small microphyllous (e.g., *Lycopodium*, *Equisetum*) or large macrophyllous (e.g., *Pteridium*, *Pteris* and other ferns).

(5) All the vegetative parts possess vascular tissues (i.e., xylem and phloem) organized in definite groups or steles.

### Spore producing organs

The plants of pteridophytes are sporophytes. They reproduce asexually by forming spores in sporangia. They are **homosporous** but a few plants are **heterosporous** also e.g., *Isoetes*, *Selaginella*, *Marsilea*, *Regnellidium*, *Pilularia*, *Azolla* and *Salvinia*. In *Selaginella* the sporangia are borne in relation to sporophylls which constitute a strobilus. In *Equisetum* they are borne on sporangiophores which constitute a cone. In ferns the sporangia are borne in **sori** on the sporophylls. The sori are of three types :

(1) **Simple sorus** : Here all the sporangia mature at the same time.

(2) **Gradate sorus** : Here the oldest sporangium lies in the centre and the sporangia on either side show successively younger stages.

(3) **Mixed sorus** : It shows mixed arrangement of younger and older sporangia.

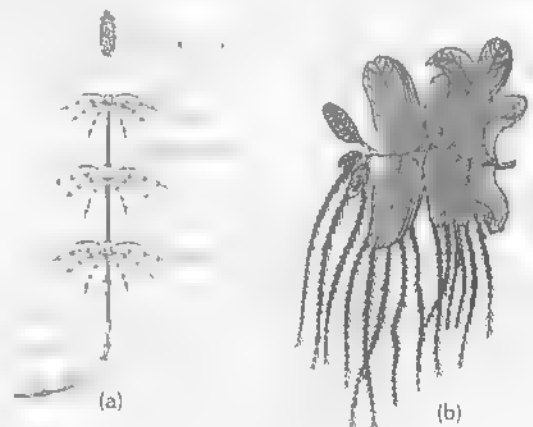


Fig : 1.6-12 Pteridophytes (a) *Equisetum* (b) *Salvinia*

### Sporangium

The sporangia are generally stalked structures. Each sporangium is distinguishable into a jacket enclosing a mass of sporogenous tissue. The sporangial jacket may be 2-4 layered. The innermost wall layer is the tapetum. No tapetum is formed in *Psilotum* and *Tmesipteris*. It is a nutritive layer which degenerates at maturity of the sporangium. The sporangial jacket in some ferns shows distinctions of annulus and stomium. On the basis of development, the sporangia have been classified by Goebel, 1881 into two categories as under :



(1) **Eusporangiate type** : Such a sporangium develops from a group of superficial initials. They divide periclinally into outer and inner components. The outer cells form the wall whereas the inner cells give rise to sporogenous tissue. e.g., *Selaginella*, *Equisetum*, *Lycopodium*.

(2) **Leptosporangiate type** : Such a sporangium arises from a single superficial initial. It divides periclinally into outer and inner components. While the inner cell forms the stalk, the outer gives rise to sporangium proper. In *Marattia alata*, the sporangia in a sorus may fuse to form a synangium. e.g., *Salvinia*, *Azolla*.

### Spore

The plants may be homosporous, i.e., produce only one type of spores (e.g., *Lycopodium*, *Pteridium*) or heterosporous i.e., produce two different types of spores, smaller microspores and larger – megaspores (e.g., *Selaginella*, *Marsilea* etc.). The spore germination in homosporous pteridophytes may be bipolar (e.g., *Lycopodium*, *Equisetum*) or tripolar (e.g., *Hymenophyllum*) or amorphous (e.g., *Angiopteris*).

### Sex organs and Fertilization

The archegonia and antheridia are generally of embedded type. The archegonium consists of neck which usually projects from the surface of the prothallus. It contains 1-2 neck canal cells. There is no venter. The egg and the venter canal cell remain surrounded by the cells of prothallus. The antheridia are generally sessile. They have a 1-cell thick jacket enclosing a mass of androgonial cells. They form the androcytes which are metamorphosed into biflagellate (*Lycopodium*, *Selaginella*) or multiflagellate (*Equisetum*, ferns) antherozoids.

**Fertilization** is affected by water medium (zooidogamous). The antherozoids are attracted towards the egg by a chemotactic stimulus provided by the degeneration of neck canal cell and venter canal cell, in the form of malic acid.

### Embryogeny

As a result of fertilization the zygote is formed. It divides into an upper or anterior **epibasal cell** and a lower or posterior **hypobasal cell**.

In *Selaginella*, *Lycopodium* the epibasal cell forms the suspensor and the hypobasal gives rise to embryo proper. By further segmentation a quadrant and then an octant is formed. Usually the epibasal quadrant forms the stem and root and the hypobasal gives rise to foot and root.

The young sporophyte of pteridophytes is dependent upon the gametophyte for food which is drawn with the help of its foot. Like bryophytes, the pteridophytes also show heteromorphic alternation of generations.

### Stelar system

The **stelar theory** was proposed by Van Tieghem and Douliot (1886). Some important types of steles found in pteridophytes are :

(1) **Protostele** : Solid core of xylem surrounded by phloem, pericycle and endodermis. The types of protosteles are :

**Haplostele** : A protostele having a central smooth core of xylem surrounded by phloem, pericycle and endodermis e.g., *Selaginella* sp., *Lygodium*, etc.

**Actinostele** : A protostele having star-shaped xylem core with radiating ribs e.g., *Psilotum*, *Lycopodium serratum*, etc.

**Plectostele** : A protostele having xylem broken into parallel plates alternating with parallel phloem plates e.g., *Lycopodium clavatum*.

**Mixed protostele** : A protostele having several xylem groups scattered and embedded in phloem e.g., *Lycopodium cernuum*.

(2) **Siphonostele** : A stele having central pith. It is formed by medullation (or appearance of pith) in the protostele. The types of siphonosteles are :

**Ectophloic siphonostele** : The central pith is surrounded by xylem, phloem, pericycle and endodermis. The phloem occurs only outside the xylem e.g., *Osmunda*.

**Amphiphloic siphonostele** : The ring of xylem is surrounded on both outer and inner sides by phloem, pericycle and endodermis e.g., *Marsilea* rhizome, *Adiantum pedatum* rhizome.

### Modification of siphonostele

(1) **Cladosiphonic siphonostele** : A siphonostele not perforated by leaf gaps e.g., a few species of *Selaginella*.

(2) **Phyllosiphonic siphonostele** : A siphonostele perforated by leaf gaps e.g., *Nephrolepis*.

(3) **Solenostele** : A siphonostele perforated by leaf gaps which are scattered but not overlapping e.g., Ferns.

(4) **Dictyostele** : A siphonostele perforated by several overlapping leaf gaps. Each separate strand is called meristele. e.g., *Dryopteris*, *Pteridium*, *Pteris*, etc.

(5) **Polycyclic dictyostele** : A dictyostele consisting of two or more concentric rings of meristeles e.g., *Pteridium aquilinum*.

(6) **Eustele** : Much dissected siphonostele having vascular strands separated apart by parenchyma e.g., *Equisetum*.

## Heterospory

The sporophytes reproduce asexually producing spores in sporangia. When all the spores are alike i.e., almost of the same size, the phenomenon is called homospory. However, in some pteridophytes, two types of spores are formed which differ significantly in their size as also in function. This phenomenon is called as heterospory. It is seen in pteridophytes like *Selaginella*, *Isoetes*, *Stylites*, *Marsilea*, *Regnellidium*, *Pilularia*, *Azolla*, *Salvinia* and *Platyzoma*.

## Apogamy, Apospory and Parthenogenesis

The terms **apogamy** was coined by de Bary (1878). It is defined as formation of sporophyte from a gametophytic cell other than egg without fertilization. It was first observed by Farlow (1874) in *Pteris cretica*. Thereafter it was observed in several other plants e.g., *Lycopodium*, *Selaginella*, *Nephrodium*, *Lastrea*, *Marsilea* etc. The apogamy is of two types, **obligate** and **facultative**.

The formation of gametophyte from a sporophytic cell without meiosis is called as **apospory**. This phenomenon was first observed by Druery (1884) in *Athyrium filix-femina*. Thereafter it has been established in several pteridophytes. e.g., *Pteridium aquilinum*, *Asplenium*, *Trichomanes* etc. Induced apospory was seen in *Pteris* species.

Formation of sporophyte from egg without fertilization is called as parthenogenesis. Farmer and Digby (1907) observed that in homosporous, leptosporangiate ferns, apospory was always followed by parthenogenesis. This phenomenon has been observed in several species of *Selaginella* and *Marsilea*.

## Economic Importance

(1) **Ornamental value** : Many ferns are grown as ornamental plants in gardens for their large and graceful foliage. e.g., species of *Lycopodium*, *Nephrolepis*, *Selaginella*, *Lygodium*, *Anemia*, *Cyathea* etc.

(2) **Medicines** : An anthelmintic drug is obtained from the rhizomes and petioles of the fern *Dryopteris*. *Lycopodium clavatum* is used in skin diseases. *Equisetum arvense* has diuretic properties.

(3) **Food** : The sporocarps of *Marsilea* are rich source of starch and used by tribals for their nutritive value.

(4) **Soil conservation** : Plants like *Selaginella* are useful in soil conservation.

## Some representative pteridophytes

### *Selaginella*

#### Habitat

*Selaginella* is commonly called the little club moss or spike moss. *Selaginella* is mainly found in damp shaded places. A few species are xerophytic and can withstand the dry conditions for months together. In dry conditions, the plant rolls up into a

compact ball and root system is disorganized. During the rainy conditions the ball on absorbing moisture, becomes green again. Such plants are called **resurrection plants** or **bird's nest moss**, e.g., *S. lepidophylla* and *S. pilifera* are xerophytes and sold in the market as novelties, *S. bryopteris* (Sanjeevani) and *S. rupestris* (ornamental).

The common epiphytic species are *S. chrysocaulos*, *S. kraussiana*, *S. oregana*, *S. chrysorrhizas*.

#### Structure

**External structure** : The plant body is sporophytic ( $2n$ ), which is an evergreen and delicate herb having adventitious roots. The plants show great variation in their morphology. Some species are prostrate growing upon the surface (e.g., *S. kraussiana*), some are suberect (e.g., *S. trachyphylla*) and others are climbers (e.g., *S. allegans*). The stem is covered with four rows of small leaves, out of these two rows are of smaller leaves and two of large leaves species with dimorphic leaves such as *S. kraussiana*, *S. helvetica*, *S. lepidophylla*, *S. chrysocaulos* etc.

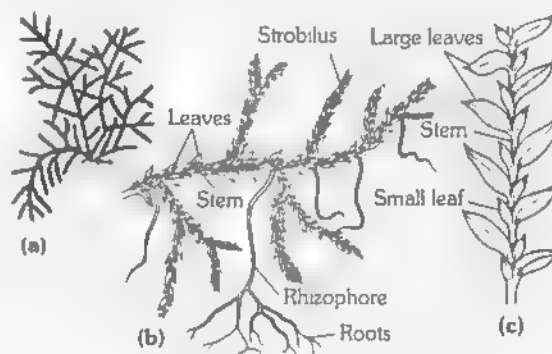


Fig : 1.6-13 *Selaginella kraussiana* : (a) General habit (b) A part of the plant (c) Small portion of plant showing arrangement of leaves

Leaves are sessile, ovate or lanceolate with acute apex. Unbranched midrib is present in the centre of each leaf. The leaves are ligulate, i.e., a flap-like outgrowth is present at the base on adaxial side called ligule. It may be fan-shaped or tongue-shaped or lobed or fringed. At the base of ligule, there is present a sheath of elongated cells called glossopodium (secretory).

The leaves possess a midrib but there is **no venation**. At the place of bifurcation of stem, a leafless, colourless, positively geotropic, elongated, cylindrical structure grows downwards. This is called the rhizophore and is quite different from the root in that it has no root cap.

#### Internal structure

**Root** : In root the stele is a protosteles. It has a central core of xylem surrounded by phloem which is **horse shoe shaped**. It has a single protoxylem element (monarch). The xylem is exarch.

**Stem** : The stem is internally distinguishable into a single layered epidermis having no stomata. This is followed by cortex. The stele is suspended by unicelled (rarely multicelled) trabeculae (modified endodermal cell).



This layer, due to presence of casparian strips is regarded as endodermis. The stele is a protostele (haplostele) surrounded by a pericycle with a central core of xylem enclosed by phloem. Protostele is **diarch** and **exarch**. Stem of *Selaginella kraussiana* shows distelic condition. More than one steles are present in the stem of some pteridophytes (i.e., polystelic condition) e.g., steles are present in *S. laevigata*.

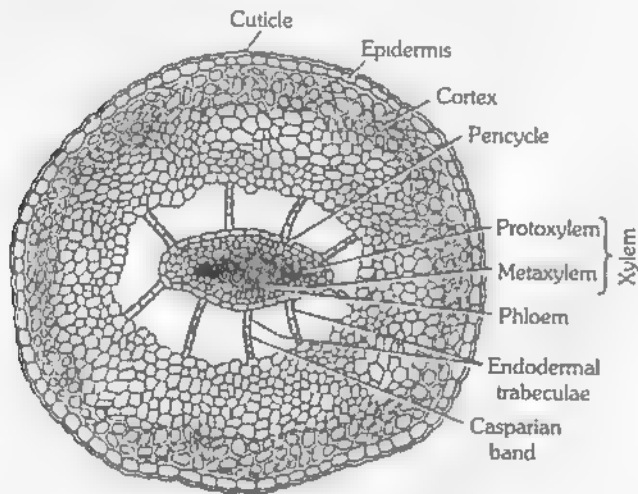


Fig. 1.6-14 T.S. stem of *Selaginella*

**Leaf :** The leaf displays a simple structure. The mesophyll is uniform, being composed of elongated chlorenchymatous cells with large intercellular spaces. Each mesophyll cell has one (*S. martensii*), two (*S. kraussiana*) or eight (*S. willdenovii*) chloroplasts. Each chloroplast has several pyrenoid-like bodies similar to *Anthocerotales*. The single midrib bundle is concentric, amphicribal (ectophloic) with annular or spiral tracheids surrounded by a few sieve elements.

**Rhizophore :** Its anatomy is similar to root. The stele is a protostele. The xylem is exarch and monarch with several protoxylem groups. In *S. kraussiana*, centroxyletic condition (having protoxylem in the centre surrounded by metaxylem elements) has been recorded.

### Reproduction

Reproduction takes place by vegetative and sexual (by spores) method.

(1) **Vegetative reproduction :** It is of rare occurrence and may take place by following methods :

**Fragmentation :** It occurs during very humid conditions. Some branches act as adventitious branches, which get separated from the plant and give rise to new *Selaginella* plants, e.g., in *S. rupestris*.

**By resting buds :** In some cases, terminal leaves get overlapped and become fleshy and form resting buds, which are means of vegetative reproduction, e.g., in *S. chrysocaulos*.

**By tubers :** In *S. chrysorrhizos*, some branches penetrate into substratum and at terminal ends swell to form tubers, which give rise to new plants.

**By apogamy :** In some cases, development of sporophyte occurs directly from gametophyte without intervention of sex organs, it is called apogamy and such plants are genetically **haploid**

(2) **Sexual reproduction :** The reproductive structure in *Selaginella* is strobilus or spike. It is a sessile structure and develops at the terminal ends of the branches and its length varies from 1/4<sup>th</sup> of an inch to 2-3 inches in different species.

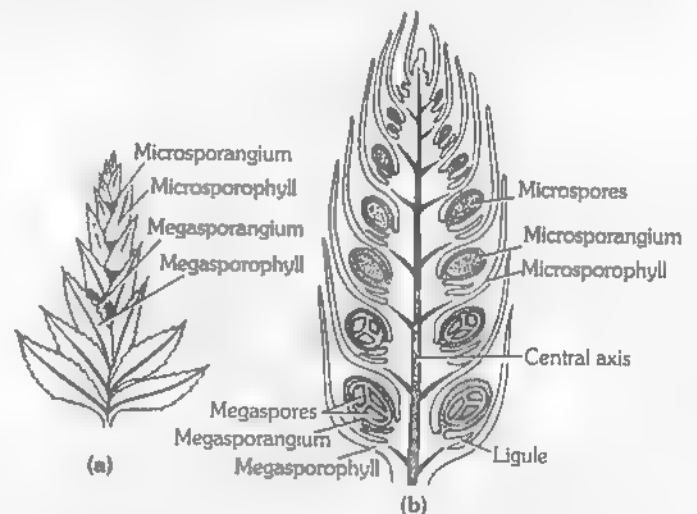


Fig : 1.6-15 *Selaginella* : (a) A strobilus showing compactly arranged sporophylls (b) L.S. through strobilus

A strobilus is having many ligulate sporophylls arranged in cluster, each bearing a small, short, stalked sporangium on its upper surface. The sporangia are of two types :

(i) **Megasporangia :** Borne on megasporophylls. Megasporangium is pale greenish and contains chalky white, yellow or orange **megaspores**.

The megasporangium is **four-lobed** structure with a 2-layered jacket, one layer of tapetum and a large number of microspore mother cell. However, only one megaspore mother cell is functional. After meiosis it produces 4 megaspores out of which 1-3 may degenerate. In *S. rupestris*, there is only a single megaspore.

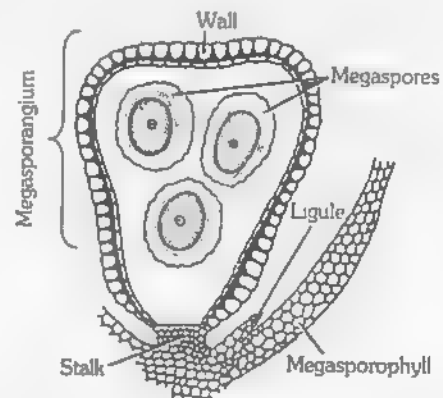


Fig : 1.6-16 *Selaginella* : V.S. of megasporangium

(ii) **Microsporangia :** Borne on microsporophylls having a large number of small spores. Thus *Selaginella* is heterosporous. Microsporangium is pale yellow, oval or spherical body, with 2-

layered jacket, one layered tapetum and a number of microspore mother cells which undergo meiosis and form haploid microspores. The main body consists of a wall having two layers, inside which are present numerous small microspores (400–2000). Development of sporangium is of eusporangiate type.

In most of the cases, the strobilus or spike bears two types of sporophylls; the lower are megasporophylls and the upper ones are microsporophylls. In *S. kraussiana* there is single megasporophyll at the base of spike and the rest of upper are microsporophylls.

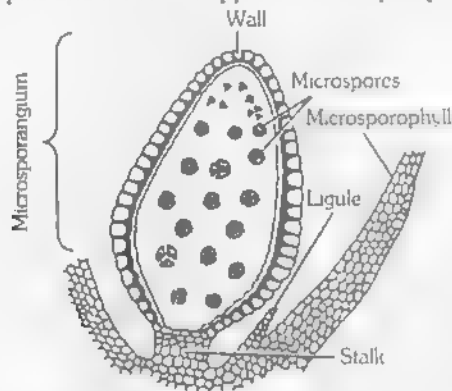


Fig : 1.6-17 *Selaginella* : V.S. of microsporangium

**Mechanism of sporangial dehiscence :** On maturation, the sporangium splits vertically from the upper end into two valves (vertical apical splitting). The lower cup-shaped portion shrinks and the spores come out through apical slits. This is brought about by cohesion owing to hygroscopic changes in the apical and lateral part of the sporangial wall. This liberation of spores takes place at intervals in small masses.

**Germination of microspore :** The microspore is a double layered structure and contains oil droplets. The outer wall exospore is much thicker (spiny) than inner endospore. It measures 15–50 $\mu$  in diameter. The microspore on germination forms the male gametophyte. The structure and development of male gametophyte was first described by Slagg (1932). The first division leads to formation of a small prothallial cell and a large antheridial cell.

The larger antheridial cell, by further divisions, gives rise to central group of four primary androgonial cells, surrounded by eight jacket cells. At this 13-celled stage (1 prothallial + 8 jacket cells and 4 primary androgonial cells), the microspore is shed from microsporangium. Each of the central groups of cells divides and redivides and finally forms about 256 spirally coiled antherozoids with two flagella (biflagellated), the jacket cells disintegrate. It takes about three weeks for germination of microspore and formation of antherozoids or sperms.

**Germination of megaspore :** The megaspore has three wall layers namely exospore, mesospore and endospore. It measures 1.5 – 5.0 mm in diameter. The megaspore on germination forms the female gametophyte. Generally the megaspore germinates inside the megasporangium (i.e., in situ). In some sps., megaspores are shed after the development of first archegonium, i.e., in *S. kraussiana*, while in *Sapoda* and *S. rupestris*, megaspores are not liberated till a well developed embryo is formed.

During the development of female gametophyte, the protoplasm after contraction forms a small sac-like structure. The outer wall bursts into two layers, the exospore and mesospore. At this stage, megaspore contains a haploid nucleus which by division produces many nuclei. Wall formation takes place in the upper beak-like portion and a small-celled cellular tissue is formed. This is one celled thick at the sides and three celled thick in the middle. This is female prothallus. Some superficial cells at apex enlarge and act as archegonial initials and form the archegonia. The megaspore bursts exposing the female prothallus. Vestigial rhizoids develop.

Archegonium are sessile and embedded type and consists of very short neck having a single neck canal cell and a venter, having a single ventral canal cell and an egg.

#### Fertilization

Usually the male gametophytes are shed from the microsporangium on the ground at 13-celled stage (one prothallial cell + 8 jacket cells + 4 androgonial cell). Here they complete their development ultimately producing spermatozoids. These are liberated by the decay of the microspore wall. If the microspore falls near the mature female gametophyte, the sperms swim from the male gametophyte to reach archegonia and one sperm fuses with egg to form zygote. Water is necessary for fertilization and sperms are attracted due to **malic acid**.

#### Development of embryo or Sporophyte

The oosphere after fertilization gets surrounded by wall and become oospore. The oospore (zygote) divides transversely into two cells, the upper epibasal cell which forms suspensor cell and the hypobasal cell which develops into embryo.

The embryo differentiates into foot, root, primary stem with two rudimentary leaves and rhizophore. By growth of stem and the root, the young sporophyte becomes independent of the gametophyte tissue and falls on the ground where the primary rhizophore forms roots that grow into the soil and the plant starts independent life.

In some species of *Selaginella*, the archegonial initial develop apogamously into embryo. In *S. intermedia*, no microspores are formed. Here the embryo develops parthenogenetically from the egg. In *S. helvetica*, the archegonia fails to open and here also parthenogenetic development of embryo is seen.

There is distinct **heteromorphic** alternation of generations in *Selaginella*.

### *Pteris, Dryopteris and Pteridium (Fern)*

#### Habitat

Ferns live in moist, cool and shady places. They are perennial and evergreen. Fern *Dryopteris filix-mas* is commonly known as **Beech fern** or **Male shield fern** or **Hay scented fern**. There are about 150 sps. and 25 sps. have been reported in India. It is found in sub-tropical regions as well as warm temperate regions.

### Structure

Fern plant is sporophytic ( $2n$ ) with an underground rhizomatous stem, large aerial leaves or fronds and adventitious roots. Rhizome is sparingly branched in *Dryopteris*, moderately branched in *Pteris* and *Adiantum* (*Adiantum* is commonly called "Maiden hair fern" or walking fern because it propagates vegetatively by its leaf tips) and profusely branched in *Pteridium*. The younger leaf is called like a spring from apex downwards are called circinate venation. The venation (arrangement of veins) in leaf is open furcate type.

Younger parts of leaves and rhizome are surrounded by brown hairy structures called **scales** or **ramenta**. Leaf bases are persistent.

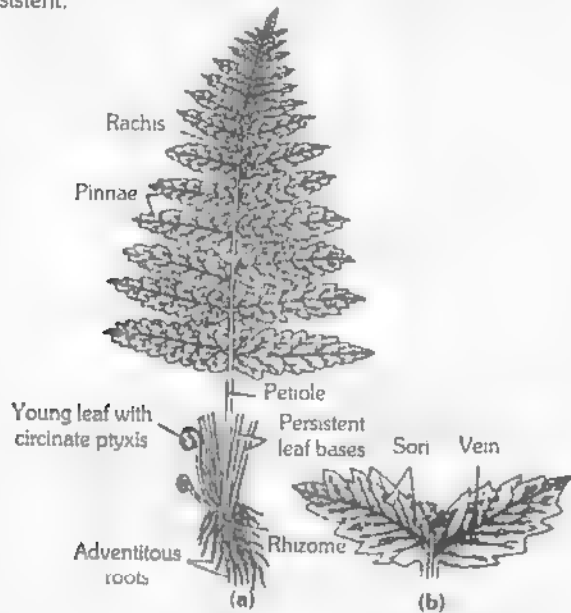


Fig : 1.6-18 *Dryopteris* (a) Plant showing habit (b) Fertile pinna

**Root** : In root the xylem is diarch and exarch with two phloem groups alternating the protoxylem.

**Rhizome** : Meristemes are found in fern rhizomes. Each meristeme has its own endodermis followed by thin walled pericycle. It is amphicribal with mesarch xylem. The phloem lacks companion cells. In *Dryopteris filix-mas* the vasculature comprises a dictyostele consisting of a ring of meristemes. In *Pteris*, however, the vasculature ranges from solenostele to polycyclic dictyostele.

**Rachis** : In the rachis of *Dryopteris filix-mas* there are 6–8 meristemes arranged in a horse-shoe like manner and single arched with hooked xylem in *Pteris*. The structure of the meristeme is similar to that of rhizome.

**Leaf lamina** : Transverse section of lamina exhibits cuticularised upper and lower epidermis having chloroplast. The vascular strands lie embedded in mesophyll. Each strand is generally amphicribal but sometimes they are bicollateral also. The bundles in minor veins are collateral.

### Reproduction

**Vegetative reproduction** : Vegetative reproduction can occur through fragmentation or rhizome and adventitious buds and these on separation gives rise to new fern plant.

**Sexual reproduction** : Sexual reproduction takes place through spores. Spores are born in sporangia. The spores are of one kind only (homosporous). When leaves are mature they bear groups of sori on the under surface of fertile pinnae. Such fronds are called sporophylls.

Sori are linear and submarginal in *Pteris* and *Pteridium* and median abaxial in *Dryopteris*. Each sorus is surrounded by a kidney-shaped covering called indusium. In *Dryopteris*, true

indusium is present because this arises from placenta or placental tissue, from which sporangia arise. (In *Pteris* false indusium is there because it is formed by leaf margins).

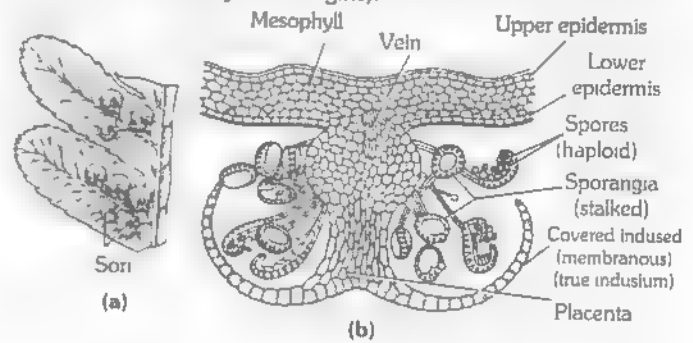


Fig : 1.6-19 *Dryopteris* (a) Part of sporophyll with sori (b) T.S. of sorus

In sorus of *Pteridium* is covered by two flap like appendages that protect the sporangia. The upper flap is called false indusium and lower is called the true indusium. In the centre of sorus, the vein ends into placental tissue from where arise a number of sporangia. The sorus is mixed in *Dryopteris* (i.e., no definite arrangement of sporangia).

**Sporangium** : The sporangial development is leptosporangiate i.e., it develops from a single superficial initial. (In eusporangiate type the sporangium arises from a group of initials). A sporangium is distinguishable into a stalk and a capsule. The stalk is multicelled and biseriate.

The capsule is oval or elliptical and biconvex in shape. It consists of a single layered wall followed by double layered tapetum that encloses the archesporium. The archesporial cells divide and redivide to form a mass of sporogenous tissue. Most of the sporogenous cells behave as spore mother cells. They undergo meiosis to form tetrahedral tetrads of (haploid) spores. As a result 32–64 spores are formed in each capsule. The tapetal layer is nutritive. It degenerates at maturity of the sporangium.

### Gametophytic generation

**Spores** : It is the first cell of gametophytic generation. Spores are double layered. The outer wall **exospore** is much thicker than inner **endospore**. On approach of favourable condition spore germinates to form a filamentous gametophyte which develops into green, dorsiventral and heart shaped prothallus.

**Prothallus** : Fern prothallus is monoecious but protandrous (antheridia mature first). Antheridia are present in between the rhizoids while archegonia are present near the apical notch.

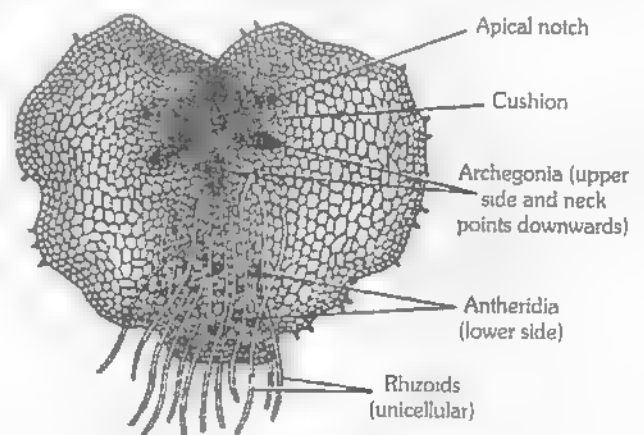
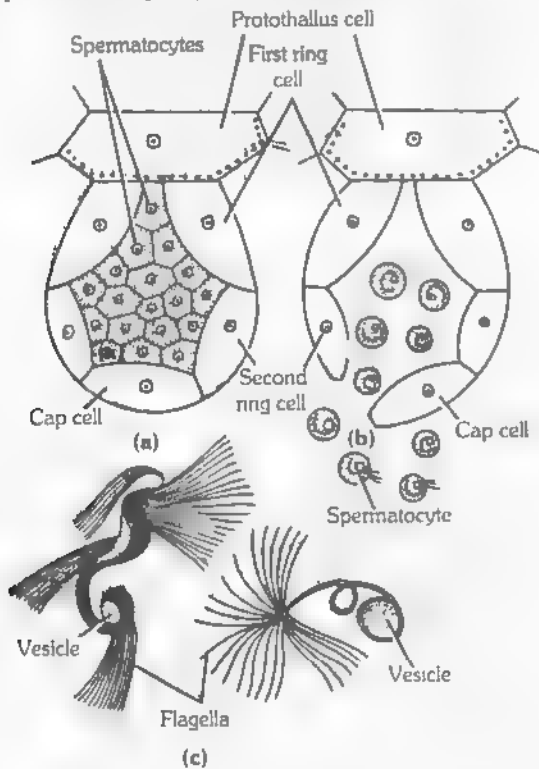


Fig : 1.6-20 Mature prothallus of *Dryopteris*

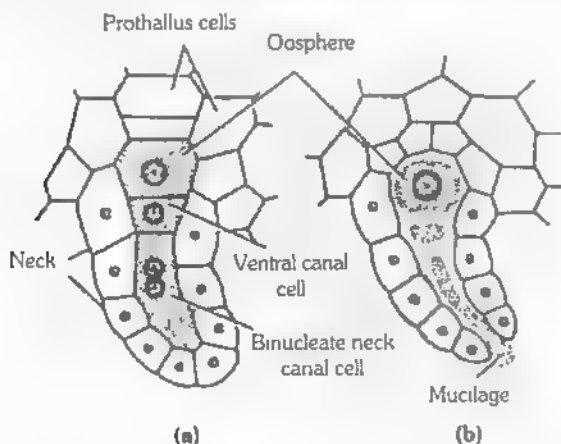
**Antheridium** : It consists of a three celled jacket enclosing a mass of androgonial cells. The two lower jacket cells are ring like (first and second ring cells), and the terminal cell is called as opercular cell or cover cell or cap cell. Sometimes, there may be two cap cells and in that case the jacket is four celled. The last generation of androgonial cells forms the androcytes. There may be 20-25 androcytes in an antheridium, each of which metamorphose into a spirally coiled, multiflagellate antherozoid.



**Fig : 1.6-21 Dryopteris (a) L.S. antheridium (b) dehiscent antheridium (c) Multiflagellate spermatozoids**

**Archegonium** : It is a flask-shaped structure having venter and neck. Neck is projected out of the prothallus and is curved posteriorly.

Venter is having basal large egg cell and upper small venter canal cell. The neck is having single neck canal cell but is binucleate. Venter is not having any covering or jacket but neck is surrounded by jacket of 4 vertical rows of cells.



**Fig : 1.6-22 Dryopteris (a) Mature archegonium (b) Before fertilization**

#### Fertilization and development of sporophyte :

Fertilization takes place in the presence of water. The antherozoids are attracted towards archegonium due to the presence of malic acid in the mucilage oozing out from archegonia.

A single antherozoid is able to fuse with egg to form zygote (2n), which is beginning of sporophytic generation.

Zygote divides first by vertical division, followed by another vertical division and quadrate stage is formed. Then octant stage is formed by transverse division.

The foot and root develop from four hypobasal cells and cotyledons as well as stem develop from epibasal cells and thus sporophytic plant is formed. At maturity foot is hemispherical mass of gametophyte from which it absorbs food.

Generally a single sporophytic plant develops from single gametophyte or prothallus. The fern sporophyte is initially dependent upon gametophyte but later on becomes independent.

The life cycle is diplohaplontic with heteromorphic alternation of generation.

#### Gymnosperm

(Gk. *Gymnos* = naked; *sperma* = seed)

The term gymnosperm was introduced by Theophrastus. Gymnosperm (Gk. *Gymnos* = naked ; *sperma* = seed) are the plants with exposed or naked seeds or ovules. These plants represent the most ancient group of seed plants. Gymnosperms are called fruitless phanerogames or flowering plants without ovary. Robert Brown (1827) separated them from angiosperms and placed under a distinct group due to presence of unprotected ovules in them. The gymnosperms originated much earlier than angiosperms. However, most of the members of this group have now become extinct and only few living forms are known today.

#### Distribution

Plants of gymnosperms occur throughout the world. The group is presently represented by only 900 living species. Of these, about 500 species belong to 'Conifers' or cone bearing plants. Several species of conifer occur in north-west America and eastern and central China. In India several members are found in Himalayas, *Podocarpus* and *Cupressus* in the central and *Larix*, *Tsuga*, *Cephalotaxus* in the eastern.

#### Habit

Living gymnosperms are mostly perennials, xerophytic, evergreen, arboreal and woody plants. They grow as woody trees, bushy shrubs or rarely as climbers (e.g., Gnetales). None of them are herbs or annuals.

#### External features

(1) The plant body is sporophyte and differentiated into root, stem and leaves.

(2) The plant possess well developed tap root system. In some cases the roots are symbiotically associated with algae (e.g., Coralloid roots of *Cycas*) or with fungi (e.g., Mycorrhizal roots of *Pinus*).

(3) The stem is erect, aerial, solid, woody and branched (unbranched in Cycadales) but almost tuberous in *Zamia*.

(4) The leaves may be microphyllous or megaphyllous.

(5) In gymnosperm xylem is generally made up of tracheids but vessels have been observed in *Gnetum*, *Ephedra* and *Welwitschia*.

(6) The primitive haplocheilic type of stomata are found in *Cycas*, *Pinus*, *Ginkgo*, *Ephedra* etc.

(7) Development of oospore is meroblastic.

#### Gymnospermous wood

**Monoxylic wood :** The wood formed may be in one ring due to persistent cambium. Such a wood is called as monoxylic e.g., *Pinus*.

Cambial activity is short lived, cortex and pith are broad, parenchymatous rays are broad, wood is soft and commercially useless. e.g., *Cycas*.

**Pycnoxylic wood :** The wood is formed in more than one ring due to ephimeral nature of cambium. Such a wood is called as polyxylic.

Cambial activity is long lived, cortex and pith are reduced, parenchymatous rays are few, wood is hard and compact, wood is commercially most important and used as good quality timber. e.g., *Pinus*.

#### Reproduction

Gymnosperms are heterosporous, i.e., produce two different kinds of spores – the male microspores and the female megaspores. The spores are borne inside the sporangia. The two types of sporangia are borne on special leaf-like structures, called sporophylls. The microsporangia (pollen sacs) are borne on microsporophylls (= stamens) and the megasporangia (ovules) are borne on megasporophylls (= carpels).

The sporophylls are usually aggregated in the form of compact structures called cones or strobili. The cones are generally unisexual, i.e., the male cones are microsporangiate (pollen cones) and the female cones are megasporangiate (seed cones). The male cones are short lived whereas the female cones are long lived. The female cones remain attached on the plants for several years till the maturity or opening of the seeds.

#### Pollination

The microsporangium (Pollen sac) produces numerous light pollen grains. Pollination is anemophilous (wind pollination). The ovules are orthotropous and remain exposed on the megasporophyll. Each ovule is surrounded by integuments. It encloses the nucellus and a female gametophyte formed from the haploid megaspore. The female gametophyte contains archegonia. The pollen grains are captured by the pollination drop secreted by the micropyle of the ovule. When it dries, the grains are sucked in the pollen chamber. The pollen grains now germinate. A pollen tube is formed due to elongation of the tube cell. In *Cycas* and *Ginkgo* the pollen tube is haustorial in nature. The lower end of the tube bursts and releases the male gametes which fuse with the egg to form the zygote.

#### Fertilization

Fertilization occurs by siphonogamy, i.e., the male gametes are carried to the archegonia through pollen tube (except in *Cycas* where pollen tube functions as haustorium and fertilization occurs by zoodiogamy). Fertilization thus takes place in the absence of external water.

#### Embryogeny

The zygote undergoes free-nuclear divisions in *Cycas* followed by wall formation. There are no free-nuclear divisions in *Sequoia* and *Gnetum*. The embryo is soon differentiated into an upper haustorial, middle suspensor and lower embryonal regions. In *Pinus*, on the other hand, the zygote gets differentiated into four tiers of four cells each, designated as open tier, rosette tier, suspensor tier and embryonal tier. Cleavage polyembryony is seen in *Pinus*. The embryonal part shows differentiation of radicle, hypocotyl, cotyledons and plumule.

#### Seed

As a result of fertilization the ovule develops into a seed. The integument forms the seed coat. The middle stony layer of the integument forms the **testa** whereas the inner fleshy layer gives rise to tegmen. The nucellus persists as a cap like **perisperm**. In *Taxus* a fleshy **aril** is also present at the base as a cup like structure. The seeds of gymnosperms comprise tissue of three generations namely **parent sporophytic** (integument and nucellus), **gametophytic** (endosperm) and **second sporophytic** (embryo).

#### Living fossils

When a group of plants is represented by a single genus or species while rest of the other representatives of the group have become extinct and fossilized the long surviving individual is called a living fossil e.g., *Ginkgo biloba*. However, *Cycas* is also regarded as a living fossil because most of the cycad species are confined to tropical and subtropical regions and the group is becoming endangered. Therefore, cycads have been referred as reptiles of plant kingdom or panda of vegetable kingdom.

#### Economic Importance

(1) **Ornamentals :** Some of the gymnosperms are grown in the gardens in different parts of the world e.g., *Cycas revoluta*, *Ginkgo biloba*, *Araucaria cookii*, *A. bidwillii*, *Biota orientalis*, *Cupressus* sp., *Juniperus* sp., *Thuja* sp., *Taxus baccata*, *Cryptomeria japonica* etc.

(2) **Wood :** Several plants of this group yield useful timber. The wood of *Cedrus deodara* is used for making railway sleepers. It is also used as a structural timber and making bridges. The wood of *Callitris verrucosa*, *Pinus roxburghii*, *P. wallichiana*, *P. pinaster*, *P. lambertiana* etc. is used for making furniture. *Juniperus virginiana* wood is used for making pencils. The gymnosperm *Agathis australis* is perhaps the largest timber producing tree of the world. Soft wood of many gymnosperms is used for making toys.

(3) **Resins :** Several conifers yield resin which is obtained by tapping. By distilling the oleoresin is obtained from pines.

The resins are of three types namely hard resins, oleoresins and gum-resins. Several hard resins are obtained from living and fossil conifers which are as under :

**Copals** : Kauri copal is obtained from *Agathis australis* and manila copal from *Agathis alba*.

**Amber** : It is obtained from the fossil conifer *Pinites succinifera*.

**Canada balsam** : It is obtained from *Abies balsamea*.

**Spruce gum** : It is obtained from *Picea rubens*.

**Bordeaux turpentine** : It is obtained from *Pinus pinaster*.

**Venetian turpentine** : It is obtained from *Larix decidua*.

(4) **Essential oils** : They are obtained from several plants. These oils are used mainly in perfumery, soap industry etc. The important oil yielding plants are *Tsuga canadensis*, *Picea glauca*, *Abies siberica* and *Cedrus deodara*.

(5) **Paper industry** : The wood of several gymnosperms, particularly those of conifers is used in paper industry e.g., *Abies pindrow*, *Picea smithiana*, *Cryptomeria japonica*, *Pinus roxburghii*, *Tsuga canadensis* etc.

(6) **Edible** : The seeds of *Pinus gerardiana* (chilgoza) and *P. roxburghii* are edible. Sago is obtained from *Cycas revoluta* and *Cycas circinalis*. The seeds of *Cycas* sp. are used in the preparation of many edible products.

(7) **Medicinal use** : Species of *Ephedra* yield an alkaloid called ephedrine. It is used in the preparation of medicines for the treatment of cough, asthma and bronchitis.

### Some representative gymnosperms

#### *Pinus*

##### Habitat

It is commonly known as pine with about 90 species among which six species are found in India. (N. East and N. West Himalayas) occurring in wild state. These are *Pinus gerardiana* (Chilgoza pine), *P. Wallichiana* (Blue pine or Kail), *P. roxburghii* (Chir pine), *P. merkusii* (Teenasserim pine), *P. insularis* (Khasi pine), and *P. armandi* (Armand's pine). In addition to these, 4 spp. of exotic pines, i.e., *P. montana*, *P. laricina* and *P. sylvestris* (Scotch pine) and *P. strobus* (white pine) have been introduced in India. *P. excelsa* are found at maximum height i.e., grow upto 3500 m above sea level.

##### Structure

**External structure** : *Pinus* is an evergreen, perennial plant of xerophytic nature. Mostly the species are tall and straight. The whorled branching gives a typical conical or excurrent appearance to the plant (due to apical dominance). The plant body is sporophyte and the plants are monoecious. The plant body is differentiated into roots, stem and leaves.

**Root** : A prominent tap root is present which does not penetrate deep into the soil. Lateral roots which develop later, grow extensively and help in anchoring the plant in the soil. Root hairs are scanty. Ectotrophic mycorrhiza i.e., symbiotic association of some fungal hyphae with the ultimate branches of roots, is of common occurrence.

**Stem** : The stem is erect, thick, cylindrical and branched. The branching is **monopodial** type. The main stem is covered by scaly bark. Branches are developed from the buds present in the axil of scale leaves and appear to be in whorls. These branches develop every year and help in calculating the age of the plant.

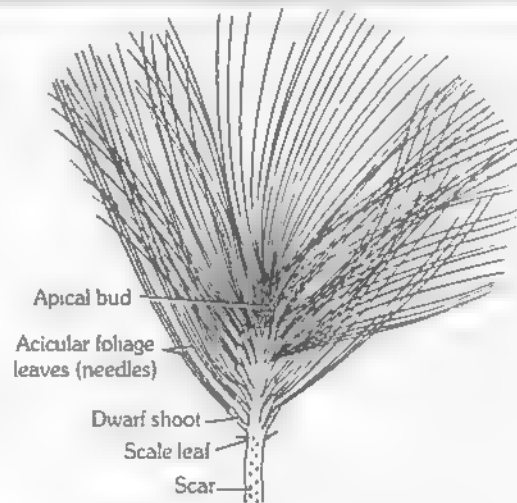


Fig : 1.6-23 A long shoot with dwarf shoots (spurs) of *Pinus roxburghii*

Branches are of two types :

(1) **Long shoots or Branches of unlimited growth** :

These have apical buds, grow indefinitely in whorls each year from the buds in the axil of scale leaves. These shoots spread out horizontally and bear scale leaves on them.

(2) **Dwarf shoots or Branches of limited growth** :

These branches lack apical buds and grow for a definite or short period. They arise in the axil of scale leaves on long shoots. The scale leaves on dwarf shoots are called the cataphylla possess a distinct midrib.

**Leaves** : The leaves are of two types i.e., **dimorphic** – scale leaves and foliage leaves.

**Scale leaves** : The scale leaves are small membranous and brown. They are present on both types of branches (i.e., long and dwarf shoots). Scale leaves are non-photosynthetic. These protect the young buds.

**Foliage leaves** : The foliage leaves are green, needle like and are born at the tips of the dwarf shoots only. Their size and number is different in different species. The dwarf shoot with needles is called a **spur**. On the basis of number of needles, spur is of different types as :

**Monofoliar** (with one needle), e.g., *P. monophylla*.

**Bifoliar** (with two needles), e.g., *P. merkusii* and *P. sylvestris*.

**Trifoliar** (with three needles), e.g. *P. gerardiana* and *P. roxburghii*.

**Pentafoliar** (with five needles), e.g., *P. wallichiana*, *P. excelsa*.

##### Internal structure

(1) **Root** : The young root of *Pinus* is identical with the dicot root. A T.S. of root reveals the following structures

**Epiblema** : It is the outermost layer of compactly arranged cells. It gives out many thin and unicellular root hair.

**Cortex** : It is composed of many layers of thin walled parenchymatous cells.

**Endodermis** : A single layer of suberized cells

**Pericycle** : Endodermis is followed by multilayered pericycle.

**Vascular tissues :** Radial vascular bundles are present.

**Xylem :** Exarch condition with bifurcated (Y-shaped) protoxylem. Resin canal is present between two arms. Xylem is devoid of vessels.

**Phloem :** Alternating with the xylem groups are present phloem patches. Companion cells are absent.

**Pith :** Pith is generally absent. If present, it is very small and made-up of parenchymatous cells.

**Secondary growth :** In young roots, cambium is absent but at maturity below the phloem patches, arches of cambium are formed. It cuts off secondary xylem on the inner side and secondary phloem on the outer side.

The cells of the outermost layer of pericycle form cork cambium (phellogen), which cuts off phellem (cork) on the outer side and phelloderm (secondary cortex) on the inner side. Finally epiblema ruptures and the cork layer is exposed.

(2) **Stem :** T.S. of a young shoot shows following tissue.

**Epidermis :** It is the outermost layer made up of small compactly arranged cells (heavily cuticularised).

**Hypodermis :** Below epidermis 4-5 layers of sclerenchymatous cells constituting hypodermis.

**Cortex :** Inner to the hypodermis is a wide zone of cortex, some cells are filled with tannin.

**Endodermis :** It is the innermost layer of the cortex, made-up of single layer of cells.

**Vascular cylinder (Stele) :** It is of eustelic type having a ring of 5-8 closely arranged vascular bundles. Vascular bundles are conjoint, collateral and open.

**Xylem :** It is endarch, consists of only tracheidal cells, vessels are absent. Therefore wood is known as non-porous.

**Protoxylem** consists of annular and spiral tracheids. Metaxylem tracheids have uniseriate bordered pits on their radial walls. These are also having bars of sanio.

**Phloem :** It is situated on the outer side of vascular bundle and is made-up of phloem parenchyma and sieve cells. Companion cells are lacking.

**Cambium :** In between the xylem and phloem of each vascular bundle, there is a strip of intrafascicular cambium.

**Medullary ray :** In between the vascular bundles is a zone of parenchymatous cells connecting the pith and the cortex.

**Pith :** In the centre of the stem is a zone of thin-walled parenchymatous cells known as pith. Some of the pith cells are filled with resinous substances.

**Secondary growth :** Secondary growth is similar to that of dicot stem. Wood is pycnoxylic and monoxyletic. Vascular rays are linear (uniseriate) but fusiform (multiseriate) area of passage of resin ducts. These cambium cells cut cells on the inner side forming secondary xylem and on outer side secondary phloem.

The ring of primary cambium remains active only for a year. The activity of the cambium stops in the winter season and again resumes in the following spring. The secondary xylem thus formed clearly shows a number of annual rings. Each annual ring consists of a zone of spring wood and autumn wood.

**Autumn wood :** It is formed during autumn season and the cells of this wood are smaller, squarish and thick.

**Spring wood :** It is formed during spring season. The cells of this wood are thinner, large and polygonal. The wood is termed as pycnoxylic (compact and hard).

(3) **Leaf (Needle) :** The outline of foliage leaf varies according to the number of needles in the spur, i.e., in monofoliar spur of *P. monophylla*, it is circular, in bifoliar spur of *P. sylvestris*, it is semicircular and is triangular in trifoliar spur of *P. roxburghii*. Internal structure of the needle is same in all species of *Pinus*. Needle shows xerophytic characters.

**Epidermis :** It has a single-layered, thick-walled epidermis, covered with thick cuticle and is interrupted by sunken stomata throughout the surface (amphistomatic).

**Stomata :** Each stoma has two guard cells and two subsidiary cells. It opens outside into a cavity called vestibule and inside into a substomatal cavity.

**Hypodermis :** Below the epidermis is present a few layered thick sclerenchymatous hypodermis. It helps in mechanical support.

**Mesophyll :** There is no differentiation into palisade and spongy parenchyma. The cells of this region are thin-walled, parenchymatous, polygonal, compactly arranged, having chloroplasts and starch grains. Peg-like infoldings arise from the inner surface.

**Vascular cylinder :** It is surrounded by single-layered endodermis having barrel-shaped cells with casparian strips.

**Pericycle :** Just below the endodermis is multilayered pericycle having a T-shaped mass of sclerenchymatous cells between two vascular bundles. Transfusion tissue occurs on the side. Each bundle is collateral, open and endarch.

The needle of *P. monophylla* has a **single** vascular bundle whereas in *P. roxburghii*, the number is **two**.

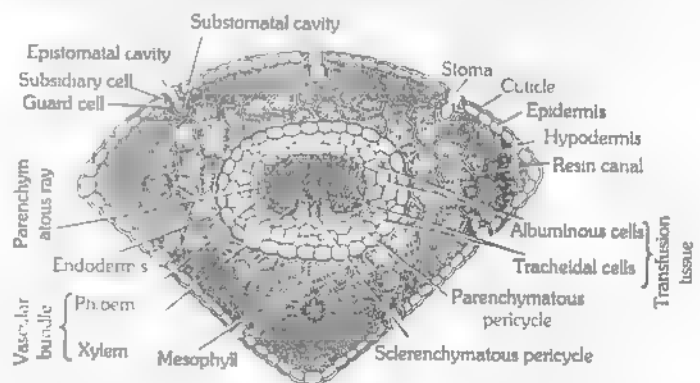


Fig : 1.6-24 T.S. needle of *Pinus roxburghii*

## Reproduction

*Pinus* reproduces only by means of spores. Unlike *Cycas*, here the micro and megasporophylls form compact male and female cone or strobilus respectively.

*Pinus* plant is sporophyte (2x), heterosporous (producing two type of spores – microspore and megaspore), monoecious (male and female cones are borne on same plant) and autoecious (male and female cones are borne on different branches).



(1) **Male cone or Staminate strobilus** : The male cones are borne in a cluster on a branch of unlimited growth behind the apical bud, in the axil of a scale leaf. A male cone is, thus, equivalent to a dwarf shoot.

In a cluster, there may be 15–140 male cones. The male strobilus is an ovoid structure measuring 2 to 4 cm. in length and 0.5 to 0.7 cm. in diameter. A cone consists of a central axis bearing 60–135 microsporophylls in spiral manner. It is, therefore, comparable to male flower of angiosperms.

**Microsporophyll** : The microsporophylls or 'stamens' are spirally arranged in a compact manner on the cone axis. The microsporophyll is a brown coloured triangular structure consisting of a short stalk or 'filament' and a leaf like flattened structure called 'anther'.

Each sporophyll is provided with two microsporangia on its abaxial surface. The terminal sterile portion of the sporophyll is turned upward to protect the upper sporangia. It is called apophysis. Some of the lower microsporophylls are sterile having no sporangia associated with them.

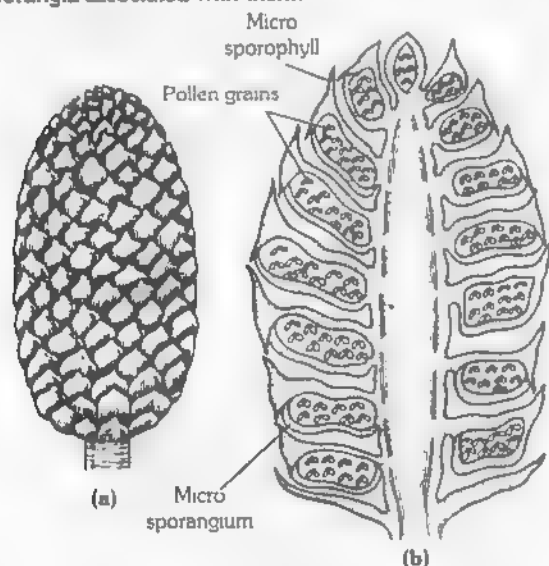


Fig : 1.6-25 (a) A young male cone of *Pinus*  
(b) Male cone in radial longitudinal section

**Microsporangium** : The microsporangia are sessile elongated, cylindrical, structures. The sporangial development is of eusporangiate type. Each sporangium consists of a 2–3 layered wall. The inner most wall layer is called tapetum, which encloses a mass of sporogenous tissue. The sporogenous cells divide and re-divide and finally behave as microspore mother cells or pollen mother cells (PMC). The PMC undergo meiosis to form tetrahedral tetrads of microspores. The tapetum is a nutritive layer which degenerates at maturity of the anther.

(2) **Female cone (ovulate strobilus)** : The female cone is an elongated, ovoid structure comprising a central cone axis on which the ovuliferous scales and bracts are spirally arranged in acropetal order. Usually the cone is 15 – 20 cm. long but in *P. lambertiana* they are 60 cm. long. The female cones take three years time to develop and mature.

The cones are produced in clusters of 1 to 4 from places where normally dwarf or spur shoots have developed. They arise in a group of 1 – 4 cones on a long shoot in the axil of a scale leaf in place of a dwarf shoot. In the first year, the female cone is reddish-green measuring about 1–2 cm in length having compactly arranged sporophylls. The second year cone is much larger, again with compact sporophylls. In the third year, the cone axis elongated and hence the sporophylls separate from each other.

**Megasporophyll** : Each megasporophyll is differentiated into two parts – Lower part is bract scale and upper part is ovuliferous scale.

**Bract scales** : These are small, dry, membranous structures attached with the cone axis directly. These are also known as carpellary or cover scales.

**Ovuliferous scale** : This is a woody, brownish structure borne on the dorsal side of the bract scale. Each ovuliferous scale is triangular with narrow basal part and upper broader part in the form of disc, known as apophysis. The apophysis appears to be rhomboidal and possesses a small point known as **umbo**.

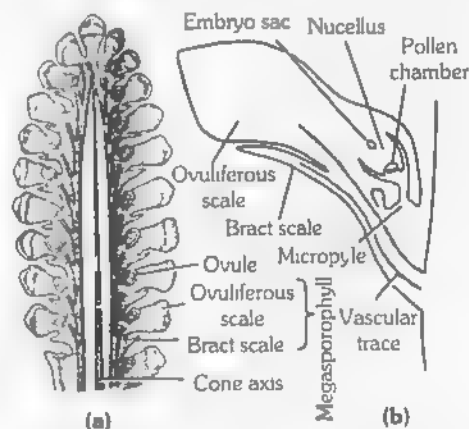


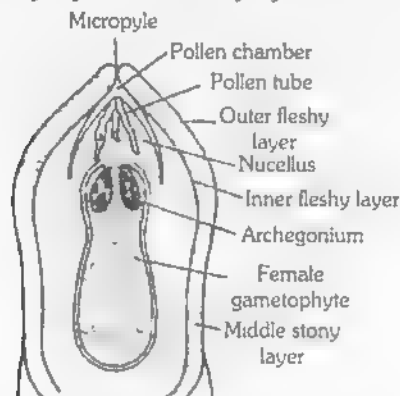
Fig : 1.6-26 *Pinus* (a) Longitudinal section of female cone (b) A megasporophyll

**Megasporangium** : Each ovule is an oval and anatropous structure consisting of a central mass of parenchymatous tissue, the nucellus, surrounded by a two lipped protective covering the integument which is united with nucellus except at the micropylar end where it prolongs to form a short tube beyond the nucellus. A small space is left in the upper region of nucellus below the integument, which is known as pollen chamber. Integument is differentiated into 3 layers although differentiation is not so distinct as in *Cycas*.

**Outer fleshy layer :** Made up of thin walled cells which disappears at maturity.

**Middle stony layer :** Very conspicuous.

**Inner fleshy layer :** Inner fleshy layer is well developed.

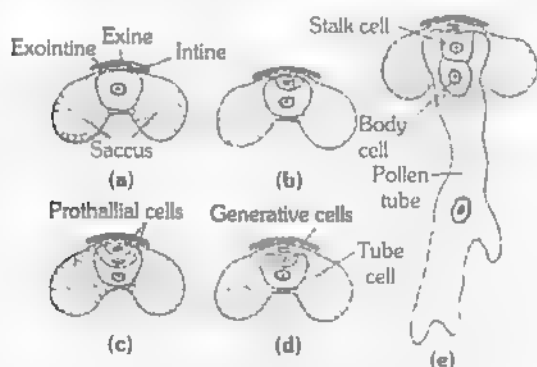


**Fig : 1.6-27 *Pinus* : L.S. of ovule showing archegonia and pollen tubes**

At the apex of the nucellus, a hypodermal cell gets enlarged and differentiated. It is called archesporial cell. The archesporial cell divides periclinally into an upper tapetal cell which forms **tapetum**, the nourishing layer, and the lower megaspore mother cell. This megaspore mother cell (sporogenous cell) divides reductionally to form a linear tetrad of haploid megaspores. Out of the four megaspores, three lying towards the micropyle degenerate. The chalazal one matures into a **functional megaspore**.

**The gametophyte :** The sporogenesis results in the formation of micro and megaspores representing the first gametophyte cells. They undergo gametogenesis so as to form the male and female gametophytes respectively.

**Male gametophyte :** The unicelled microspore undergoes three divisions of microgametogenesis, so as to form a four-celled pollen grain or microgametophyte or male gametophyte.



**Fig : 1.6-28 *Pinus* : (a)-(e) Various stages of microgametogenesis**

There are two prothallial cells, a generative cell and a tube cell. The pollen grains, at maturity are protected by three wall layers. The outermost wall layer, called exine or cappa is cutinised. the second wall layer is called exintine or capulla. It forms two

balloon like outgrowths, on either side, called wings or saccus. The third wall layer is thin and called intine or tenuitas. At maturity the microsporangia dehisce by a longitudinal slit and the pollen grains are dispersed at 4 – celled stage. Since, a large number of grains are set free from a cluster of male cones in the form of pale-yellow cloud the phenomenon is often described as **shower of sulphur** or **shower of golden dust**.

**Female gametophyte :** The functional megaspore enlarges. A vacuole develops in the centre and then its nucleus divides freely to form about 2000 nuclei. Initially, multinucleate tube like cells are formed called **alveoli**. Later, wall formation starts from periphery and proceeds towards the centre. As a result, cellular female gametophyte or female prothallus or megagametophyte or **endosperm** is formed. The cells of the nucellus surrounding the female gametophyte now get modified and form a nutritive layer called endosperm jacket or spongy layer. The 'endosperm' of *Pinus* is a haploid gametophytic tissue formed before fertilization.

**Archegonium :** Near the micropylar end, one to five archegonia are differentiated in the prothallus. Each archegonium at maturity consists of eight neck cells arranged in two tiers of four cells each and a venter having a small ventral canal cell and a large egg. The ventral canal cell disorganizes before fertilization. **Neck canal cells are absent.**

**Pollination :** The pollination in *Pinus* is anemophilous. The wings of pollen grains are helpful in pollination. Just before pollination the female cone axis elongates separating megasporophyll from each other. This facilitates pollen grains to reach ovules. There is a long interval of about a year between pollination and fertilization.

**Post pollination changes in the male gametophyte :** The exine ruptures and the intine protrudes out to form the pollen tube that grows through the nucellar tissue. Simultaneously, the generative cell divides to form a stalk cell and body cell. The body cell then divides to form two male gametes, which are non-flagellate.

**Fertilization :** The mode of fertilization was discovered by Goroschankin (1883). After reaching the neck of the archegonium, the tip of the pollen tube ruptures releasing the two male gametes. The ventral canal cell degenerates and the neck cell split apart. Out of the two, one male gamete fuses with the egg to form the zygote. The second male gamete along with the stalk and body nuclei disintegrate. This type of fertilization is called siphonogamous fertilization.

**Embryogeny :** The proembryonal development in *Pinus* was studied by Buchholz (1918). The zygotic nucleus moves toward the base and then divides to form four nuclei. These nuclei organise into four quadrately arranged (diagonally opposite) cells with open upper end. The four cells divide simultaneously thrice to form four tiers of four cells each. These tiers are designated from top downwards as open tier, rosette tier, suspensor tier and apical tier. Since only a part of the oospore is involved in the formation of the embryo, the development is said to be meroblastic.

The cells of suspensor tier elongate pushing the embryonal cells into the 'endosperm'. The four suspensor cells due to considerable elongation may become coiled. These cells may divide transversely to form secondary suspensor or **embryonal tubes**.

Another type of polyembryony found in *Pinus* is simple polyembryony i.e., when more than one embryos are developed as a result of fertilization of different archegonia. Thus in *Pinus* although both types of polyembryony are found but at maturity seed contains only one embryo as food is not sufficient for survival of many embryos. The embryo soon gets differentiated into radicle, plumule, hypocotyl and cotyledons. The number of cotyledons is always more than two (Schizocotily).

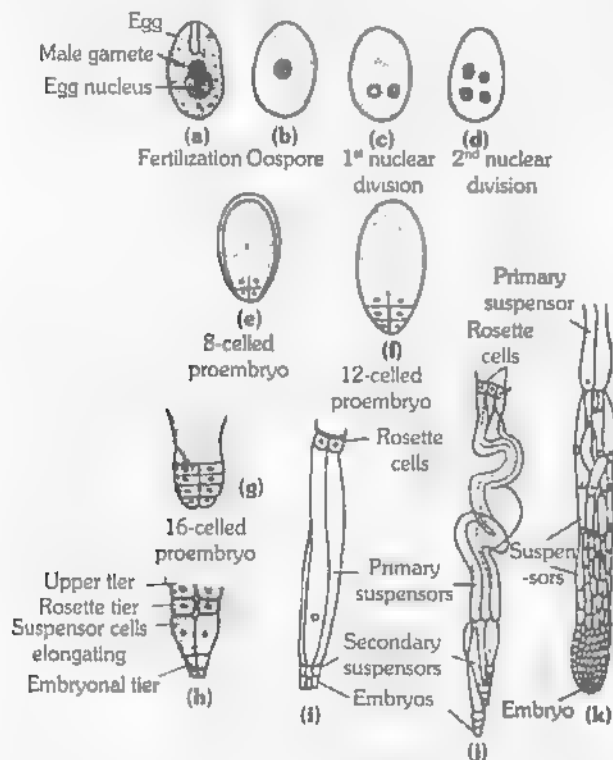


Fig : 1.6-29 *Pinus* : Embryogeny

**Seed formation :** Seed of *Pinus* is winged. The wing (saccus) develops from the upper surface of ovuliferous scale. Seed has thin with hard outer coat, which is peeled off, a stony coat, papery coat, cap like perisperm and food laden endosperm which encloses a central embryo. Embryo possesses 9–14 cotyledons (*Proxburghii*). A seed represents three generations – parent sporophyte (testa, tegmen and perisperm, if present), new sporophyte (embryo) and female gametophyte or endosperm.

**Seed germination :** The seeds may remain dormant for several years. The germination of seed occurs when the environmental conditions are favourable. The radicle protrudes out through the micropyle and enters the soil forming the primary root. The plumule comes out and along with cotyledons it is pushed in air due to elongation of hypocotyl. The germination is, therefore, epigeal. The plumule forms a few **juvenile leaves** or prophylls.

The juvenile leaves are spirally arranged on the branch of unlimited growth. Long shoots arise in their axis. Later on, they dry up as scales. The rate of growth of *Pinus* is quite slow.

#### Economic importance

- (1) Seeds of some species are edible e.g., *P. gerardiana* (chilgoza), *P. edulis*.
- (2) Fossilized resin (amber) is obtained from *P. succinifera* and is of great commercial value.
- (3) Some species of *Pinus* are cheap source of cellulose.
- (4) Some species are used for manufacture of paper.

### Cycas

#### Habitat

*Cycas* is an evergreen palm-like plant. It is the only genus of family Cycadaceae represented in India. *Cycas* has approximately 20 species found in Australia, New Zealand, Japan, China, India, Burma (Myanmar) and Pacific Islands.

In India, four *Cycas* species are common in Odisha, Bengal, Assam, Tamilnadu, Karnataka and Andaman.

(1) *Cycas revoluta* : It is a native of China and Japan and is locally called **Tesso**. In our country, it is called '**Sagopalm**'. Due to its primitive characters, it is also called living fossil. It is upto 10 ft tall.

(2) *Cycas circinalis* : Plants are about 12 to 15 ft tall and distributed upto 3500 ft. In Hindi, it is called as **Janglimadan mast-ka-phul**.

(3) *Cycas rumphii* : Plants are about 12 ft tall. It is also cultivated in Indian gardens. In Tamil, it is called **Kama, Paiyindu**.

(4) *Cycas beddomei* : It is found in Trimula-hills of Andhra Pradesh.

#### Structure

**External structure :** It looks very much like a palm tree or a tree fern, hence also called palm fern. Fully grown plants attain a height of 2–5 m although *C. media* attains a height of 20m. The main plant body is differentiated into root, stems and leaves.

(1) **Roots** : Roots arise from lower part of stem and are of two types :

(i) **Normal roots** : These form a primary tap root system. These are positively geotropic and their main function is to absorb water and nutrients

(ii) **Coralloid roots** : From the lateral branches of the normal roots are formed dichotomously branched, apogeotropic, bluish green coralloid roots. *Anabaena cycadacearum*, *Nostoc* and bacteria are found in their cortex. It is an example of symbiosis. It helps in fixation and absorption of nitrogen. As these roots possess lenticels, they also help in respiration.

(2) **Stem** : Stem is thick, cylindrical, columnar, small, aerial and unbranched. It is covered with persistent leaf bases and scale leaves, which are found in alternate whorls. There is a crown of foliage leaves at the apex of the plant.

(3) **Leaves** : *Cycas* has two types of leaves (dimorphism).

(i) **Scale leaves** : These are reduced form of foliage leaves without lamella and are arranged in a compact spiral and alternate manner around the apex and bears no reproductive structures. These are protective in nature. A single scale leaf is a brown, dry, woody, triangular structure, covered with brown hairs or ramenta.

(ii) **Foliage leaves** : These are brown scales and green unipinnately compound present on the apex of the plant forming a crown. These leaves are upto 3 metres in *C. circinalis*. Leaves are leathery and thick, some leaflets at the base of the rachis are reduced to spines. These are mainly photosynthetic in nature. Leaves in *Cycas* show xerophytic characters.

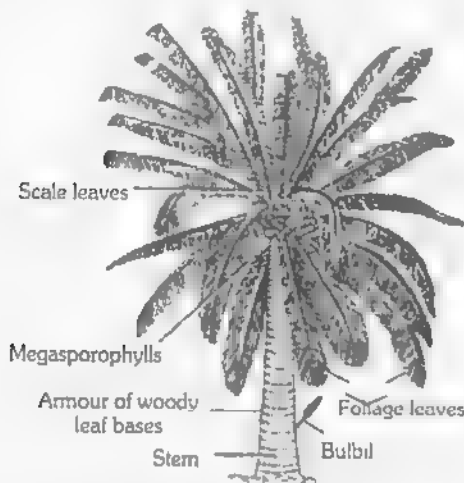


Fig : 1.6-30 External morphology of *Cycas*

#### Internal structure

##### (1) Root

**Normal root** : The structures of normal root resembles dicotyledonous root. T.S. of normal root reveals the following structures

**Epiblema** : This is the outermost layer with unicelled root hairs.

**Cortex** : Just below the epiblema is multilayered parenchymatous cortex. Some tannin cells are present in the cortex.

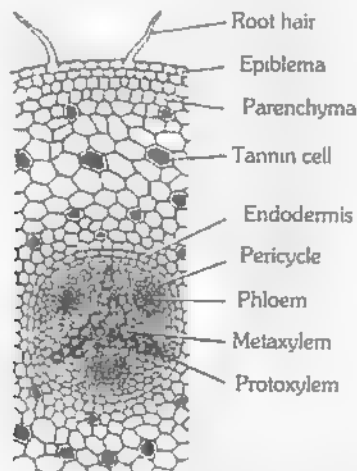


Fig : 1.6-31 T.S. normal root of *Cycas*

**Endodermis** : Below the cortex is present endodermis which is made up of barrel-shaped cells and below it is a layer of pericycle.

**Vascular tissues** : It consists of xylem and phloem which are radially arranged, i.e., on different radii

**Pith** : It is generally absent.

**Secondary growth** : It is like dicotyledonous plants.

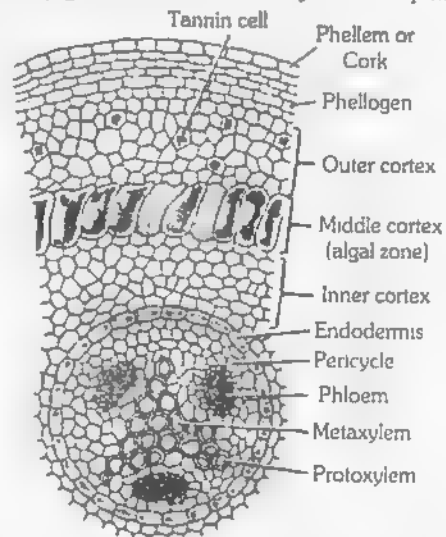


Fig : 1.6-32 T.S. coralloid root of *Cycas*

**Coralloid root** : Structure of stele is similar to normal roots but cortex is divided into three zones

**Outer cortex** : Having several layers of parenchymatous cells.

**Middle cortex (Algal zone)** : Filled with blue green algae, *Anabaena* and *Nostoc*.

**Inner cortex** : Having several layers of parenchymatous cells. Roots are diarch, triarch and sometimes polyarch.

(2) **Stem** : It resembles a dicotyledonous stem having the following tissues :

**Epidermis** : It is the outermost incomplete layer ruptured due to persistent leaf bases. It is made up of compactly arranged thick-walled cells.

**Cortex** : Cortex is large, thin-walled, parenchymatous, having a number of mucilage canals. Starch grains are found in the cortex.

**Endodermis and pericycle** : These layers are not very clear.

**Stele** : Vascular cylinder is very small having numerous small closely arranged vascular bundles, which are conjoint, collateral and open. Xylem is endarch and consists of tracheids, which have spiral thickening in protoxylem and scalariform thickenings in metaxylem. Phloem is devoid of companion cells. Albuminous cells are found in phloem.

**Leaf traces** : There are several leaf traces present in the cortex. Four vascular bundles enter the base of leaf, two of these are direct and other two arise from the stele of opposite side and after making semicircle, they enter the leaf. These indirect leaf traces are known as girdling leaf traces or leaf girdles.

**Pith** : It is large, parenchymatous and is having a number of mucilage canals. Starch grains are also found in pith.

**Secondary growth :** The secondary growth is initiated by the formation of a cambium ring due to the development of interfascicular cambium strips and their subsequent joining with the intrafascicular cambium. This ring cuts secondary xylem on the inner side and secondary phloem on the outer side in addition to secondary medullary rays on both sides. This cambium ring now ceases to function another cambium now arises from pericycle or inner layers of cortex.

The new cambium functions in the normal way like the old one. Thus, concentric rings of secondary xylem and secondary phloem are formed. Such a wood is called as polyxylic i.e., comprising more than one xylem cylinders. Due to the presence of alternating rings of thin walled tissue (phloem) the wood of xylem remains loose and hence it is described as manoxylic. The growth in the extrastelar region takes place by the formation of a phellogen (cork cambium) which cuts off phellem (cork) on the outer side and phelloderm (secondary cortex) on the inner side. The three layers jointly constitute the periderm. The secondary growth pattern of *Cycas* resembles some dicots showing abnormal secondary growth. Secondary wood is devoid of vessels.

The secondary xylem is made up of tracheids showing multiseriate bordered pits. Bars of sanio have been observed by Sifton, 1915 in the tracheids of *C. revoluta*. The secondary phloem comprises sieve cells and fibers.

### (3) Leaf

(i) **Rachis :** The cross section of the rachis is almost circular with two depressions on upper lateral sides where the leaflets are attached.

**Epidermis :** The outermost layer is epidermis with thick cuticle having stomata.

**Hypodermis :** Epidermis is followed by a well developed hypodermis, differentiated into outer chlorenchymatous and inner sclerenchymatous regions.

**Ground tissue :** Below the hypodermis is well developed parenchymatous ground tissue with mucilage canals. The vascular bundles are arranged forming an inverted omega ( $\Omega$ ). Each vascular bundle is surrounded by a sclerenchymatous sheath and is conjoint, collateral and open. In most parts of the rachis, xylem is mesarch, i.e., centripetal xylem towards periphery and two patches of centrifugal xylem one on each side of protoxylem of centripetal xylem. Outside the centrifugal xylem is cambium and then phloem towards periphery.

(ii) **Leaflet :** Each leaflet is sessile has one midrib and no lateral veins and in *C. revoluta* the margin is curved inwardly. In young condition young leaves show circinate ptyxis like fern leaves.

**Epidermis :** Epidermis is single layered with thick cuticle. The upper epidermis is complete whereas the lower epidermis is interrupted by several stomata present only in the region of blade (hypostomatic). Upper and lower epidermis are covered by layer of thick cuticle.

**Hypodermis :** Just below the upper epidermis, there are several layers of sclerenchymatous hypodermis while above the lower epidermis it is present only in the midrib portion.

**Mesophyll :** Mesophyll is differentiated into palisade parenchyma on upper side and spongy parenchyma on lower side. Palisade tissue is made up of vertically elongated cells without intercellular spaces. Both tissues contain chloroplasts.

**Vascular bundle :** In the midrib there is a large vascular bundle. The vascular bundle is collateral and closed. The xylem is mesarch, i.e., diploxylic condition with centripetal and centrifugal xylem.

**Transfusion tissue :** On each side of the midrib in between the palisade and spongy tissues is present transfusion tissue made up of horizontally arranged tracheids which supply water and mineral to mesophyll tissue upto margins

### Reproduction

*Cycas* plants are dioecious and reproduce by following methods :

(1) **Vegetative propagation :** It occurs by means of bulbils (resting adventitious buds) which are produced on the stem in the axil of scale leaves. They break up from the parent plant and germinate to give rise to new plant.

(2) **Sexual reproduction :** Plant of *Cycas* is sporophyte (2n) and dioecious. The sexual reproduction is of oogamous type, i.e., takes place by the fusion of distinct male and female gametes. The male and female gametes are formed by the germination of micro and megaspores which are born on microsporophylls and megasporophylls. The microsporophylls are grouped together to form a compact conical structure called male cone, whereas the megasporophylls are not aggregated to form a cone, they are produced at the apex of the stem in succession with the leaves

**Male cone :** The male cones are borne every year singly at the apex of the male plant. The growth of the male plant is, therefore, checked.

Later on, a lateral bud develops which pushes the male cone to one side and occupies a terminal position. The process is repeated during the formation of subsequent male cones. As such, the growth pattern of male plant is sympodial.

The male cone is a shortly stalked, oval or elliptical structure measuring about 40 – 60 cm in length. It may sometimes attain a length of 75 cm. in *C. circinalis*. Each cone consists of a central axis bearing numerous microsporophylls arranged in spiral manner.

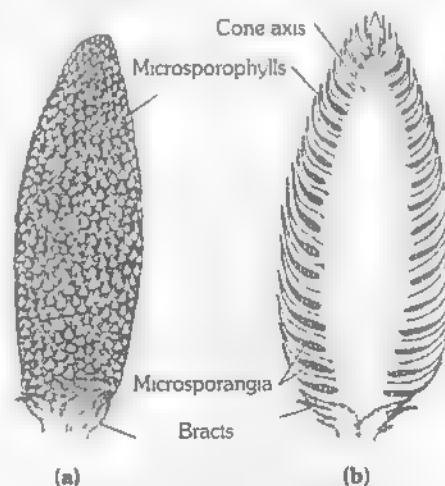


Fig : 1.6-33 *Cycas* : (a) External view of male cone  
(b) L.S. of male cone

**Microsporophylls :** They are wedge - shaped structures with a slightly broad base. They are soft and fleshy in the younger stages. At maturity, they are hard and woody. They

measure about 3 – 4 cm. in length and 1.2 – 2.3 cm. in width. They bear sori of sporangia on the abaxial (lower) surface. The terminal sterile portion of the sporophyll is called **apophysis**. In the apophyseal region the sporophyll gradually tapers and points upward.

**Microsporangium** : The microsporangia are borne in sori on the abaxial surface of the sporophyll. Each sorus contains 2 – 6 microsporangia. The number of microsporangia may be upto 700 in *C. circinalis*, 1000 in *C. revoluta* and 1150 in *C. media*. In between the sporangia are present uni or bicelled epidermal hair. The microsporangia are short-stalked, oval or elliptical structures. The development of the sporangium is of eusporangiate type. Each sporangium consists of a 5 – 6 layered wall. The outer most wall layer is called as exothecium whereas the innermost layer is the **tapetum**.

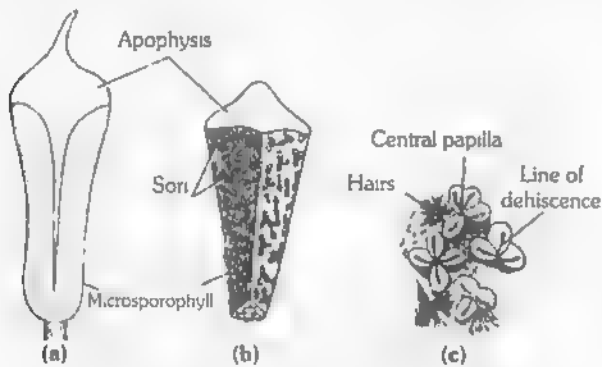


Fig : 1.6-34 *Cycas* : (a) Dorsal view of microsporophyll  
(b) Ventral view of microsporophyll  
(c) Microsporangia in sori (undeveloped)

The tapetum encloses the sporogenous tissue. The sporogenous cells divide and re-divide to form the microspore mother cells or pollen mother cells (PMC). The PMC undergo meiosis to form tetrahedral tetrads of spores. The cells of exothecium develop a thickening along their radial and inner tangential walls. The cells of tapetum and inner wall layers degenerate at maturity to provide nutrition to the developing pollen grains. The wall of a mature sporangium, thus comprises exothecium only.

**Megasporophyll** : The megasporophylls are spirally borne in acropetal order on the female plant. Since they are loosely arranged, there is no female cone formation. Each megasporophyll is regarded as a **modified foliage leaf** and is about 5 – 10 inches long. In the female plant therefore, the apical meristem remains unaffected. Hence, the growth pattern in the female plant is monopodial.

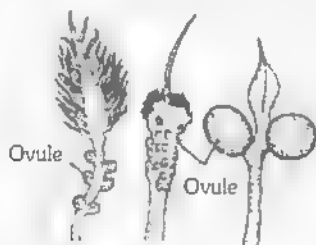


Fig : 1.6-35 Megasporeophylls of different species of *Cycas*

The megasporeophylls are flat, dorsiventral structures distinguishable into a proximal stalk or rachis part and a distal lamina. The margin of lamina is serrate or dentate in *C. circinalis*,

*C. beddomei* and *C. rumphii*. In the upper part of the rachis are present 1 – 6 pairs of ovules, laterally. This number is variable in different species e.g., 1 – 6 pairs in *C. revoluta*, *C. circinalis* and only one pair in *C. normanbyana*.

**Megasporangium (Ovule)** : The ovules of *Cycas* are **largest** in nature, can be seen by naked eyes. In *C. circinalis*, the ovules are largest in size, i.e., about 6 cm in length and 4 cm in diameter.

The ovules are orthotropous and unitegmic. The main body of the ovule is nucellus, covered by a single thick integument except at the top where a small opening is left called micropyle.

The integument is distinguishable into three layers, an outer fleshy layer (sarcotesta), middle stony layer (sclerotesta) and inner fleshy layer (sarcotesta). The outer and inner fleshy layers are vascularised as also the nucellus by separate bundles. The apex of the nucellus develops a beak-like process, the nucellar beak, which projects into the micropyle.

Somewhere in the deep layers of nucellus a megaspore mother cell is differentiated. It has a prominent nucleus and dense cytoplasm. It undergoes meiosis to form a linear tetrad of megaspores. Of these, three micropylar megaspores degenerate and the lowest functions. The functional megaspore has a thick papillate outer wall called exospore and a thin, fibrillar inner wall, the endospore.

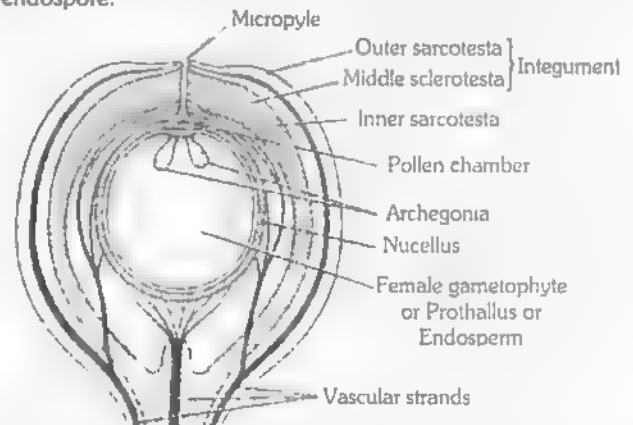


Fig : 1.6-36 L.S. megasporangium (ovule) of *Cycas*

**The gametophyte** : As a result of sporogenesis, the micro and megaspores are formed. They are the first gametophytic cells. The microspores give rise to the male gametophyte whereas the megaspores form the female gametophyte. The gametophytes reproduce sexually.

**Male gametophyte** : The unicelled microspore undergoes two divisions of microgametogenesis and as a result three cells are formed. These three cells are serially designated as tube cell, generative cell and prothallial cell. At this stage the pollen grain is double layered. The outer wall exine is much thicker than intine. The microsporangium dehisces by a longitudinal slit and pollen grains are dispersed at **3-celled stage**.

**Female gametophyte** : The nucleus of the functional megaspore divides freely to form a free-nuclear gametophyte. A vacuole appears in the centre. Wall formation now begins from periphery and gradually proceeds towards the centre. As a result,

cellular female prothallus or megagametophyte or endosperm is formed. The 'endosperm' in *Cycas* is a haploid gametophytic tissue formed before fertilization. This is nutritive in function. Simultaneously, a tiny space develops on the upperside of the ovule between nucellus and the female gametophyte due to degeneration of certain nucellar cells. This is called as archegonial chamber.

**Archegonium :** The archegonia are formed from the gametophytic cells lining the archegonial chamber. The number of archegonia formed in a gametophyte is variable e.g., 2 – 8 in *C. revoluta*, 3 – 6 in *C. rumphii* and 3 – 8 in *C. circinalis*. An archegonium consists of a two celled neck but there is no neck canal cell. There is no venter either. The egg and the ventral canal nucleus remain surrounded by the cells of prothallus. *Cycas* produces largest egg in the plant kingdom measuring 0.5 mm. in diameter.

**Pollination :** The pollination is anemophilous. The pollen grains of *Cycas* are light in weight and easily blown away by wind at 3-celled stage (prothallial cell, generative cell, tube cell). At the time of pollination, a large pollination drop comes out of micropylar end of ovule by disorganisation of nucellar beak. The pollen grains are entangled on this drop and as it dries, the pollens are drawn into the pollination chamber.

**Post pollination changes in the male gametophyte :** After a definite period of rest, the pollen grain germinates. The generative cell divides into a lower stalk cell and upper body cell. Body cell enlarges and forms several blepharoplasts, which later forms cilia.

The tube cell elongates, pierces the exine and forms a pollen tube. The pollen tube is slightly swollen and branched at tip. The pollen tube acts as haustorium absorbing food from nucellus. Body cell divides into two daughter cells and each daughter cell metamorphosis into one antherozoid or sperm or male gamete.

The male gametes of *Cycas* are largest (300 $\mu$ ) in nature, visible to naked eye and are oval in form, broad (top-shaped) and naked at posterior end and spirally coiled in the anterior half with thousands of small cilia. The sperms pass into pollen tube and reach the tip of the tube.

### Fertilization

After reaching the archegonial chamber, the tip of the pollen tube ruptures releasing the two male gametes. Besides, the tube also discharges a fluid having high concentration. When an antherozoid touches the neck cells, it is sucked in violently. By the time the ventral canal nucleus has already degenerated. As a result of syngamy, the zygote is formed

The fertilization in *Cycas* is, therefore, siphonogamous (by pollen tube) accompanied by zooidogamy (by flagellate gametes). Thus the fertilization brings to an end of the gametophytic generation and the zygote is the initial stage of sporophytic generation.

### Embryogeny

The zygote, which is the first sporophytic cell, undergoes free-nuclear divisions. A vacuole develops in the centre pushing the nuclei to the peripheral position. In the upper region there are only a few nuclei but the lower region contains numerous nuclei. This is followed by wall formation that begins from periphery and proceeds to centre (centripetal). The cellular proembryo consists of –

**Upper :** Haustorial region, **Middle :** Suspensor region and **Lower :** Embryonal region.

Embryo consists of radicle, plumule, 2 cotyledons, haustorium and suspensor. In *cycas* polyembryony is often seen as egg of almost all the archegonia are fertilized and produce embryo.

### Seed formation

The mature seed of *Cycas* is an orange-red or reddish-brown structure. The seed is covered by a thick testa. It is sweet in taste and emits pleasant odour.

These two characteristics are responsible for their zoochorous, (omithochorous) dispersal. Major parts of nucellus and inner sarcotesta are used up by the developing embryo reducing them to thin, papery layers.

The embryo is distinguishable into a haustorial tip, a long suspensor, radicle, hypocotyl, plumule and two cotyledons.

### Seed germination

There is hypogeal germination of *Cycas* seed. In germination, the radicle forms a tap root. The cotyledons remain in the endosperm under the surface of soil. The plumule grows up and forms some scale leaves and later foliage leaves. *Cycas* seed represents 3 generations :

Old sporophytic generation (represented by seed coat and nucellus), Female gametophytic generation (represented by endosperm), and Future sporophytic generation (represented by embryo).

Life history of *Cycas* is diplohaplontic. It shows heteromorphic or heterologous type of alternation of generations.

### Economic importance

(1) A starch called sago is obtained from the pith of *Cycas*, that is why *Cycas* is called **sago palm**. In Japan starch extracted from stem of *C. revoluta* is used for preparing saboodana.

(2) Seed of some *Cycads* are used as fodder for animals.

(3) Leaves are used for making mats and baskets.

(4) *Cycas* is an ornamental plants.

(5) Boiled young leaves are eaten as vegetables.





(6) Extract of young *Cycas* leaves are used in the treatment of many skin diseases.

The decoction of seeds is used as purgative. Tincture prepared from its seeds is used by Indians in headache, nausea, bad throat, etc.

## Angiosperms

(Gk. *Angelon* = covered; *sperma* = seed)

### Introduction

The angiosperms, or flowering plants, constitute the most dominant and ubiquitous vascular plants of present day flora which changed the green and yellow melancholy of the earth's vegetation by the colourful brightness and fragrance of their flower. The term angiosperm means 'enclosed seed' because the ovules or potential seeds are enclosed within a hollow ovary. In this respect they are considered most highly evolved and advanced as compared with the naked seeded gymnosperms.

### Characteristic features

(1) Angiospermous plants grow in almost every kind of habitats. In the deserts, these plants grow, flower, shed seeds and complete their life cycle in a few weeks of rainy season. Some flowering plants like *Zostera*, occur in shallow seas. A small orchid even lives underground. It survives as a saprophyte on decaying organic matter because of the mycorrhizal association which helps to obtain nourishment. In rain forests, some plants grow on the branches of other plants but do not obtain water or food from them. They are called epiphytes (e.g., *Vanda*).

(2) The angiospermous leaves show reticulate or parallel venation forming areoles. The libriform fibres are present in the xylem and the companion cells are present in the phloem. The true vessels are present in the xylem of angiosperms.

(3) The angiosperms produce flowers which normally consist of 4 whorls of appendages – the two outer accessory and reproductive structure such as sepals and petals and the two inner essential parts – stamens and carpels.

(4) The stamens (microsporophylls) are bilaterally symmetrical. Each stamen consists of a filament and an anther.

(5) The anthers produce tectate pollen grains with exine differentiated into rod-like columellae covered by a tectum.

(6) In angiosperms, the insects and animals also act as pollinating agents. For this purpose the flowers possess bright and showy petals, edible pollen and nectar.

(7) The carpels (= megasporophylls) are rolled and partly sterile so that they enclose the ovules within a hollow ovary that is connected with the stigma and style.

(8) The female gametophyte is highly reduced and consists of single egg cell, two synergids, three antipodals and two polar nuclei. The archegonia are absent.

(9) The most characteristic feature of angiosperms is double fertilization.

(i) The male gamete fuses with the egg producing diploid zygote that develops into embryo or new sporophyte.

(ii) Another male gamete fuses with the polar nuclei (triple fusion) resulting in the formation of triploid endosperm.

(10) After fertilization, the ovules ripens into seeds and ovary ripens into fruits.

### Size

(1) **The smallest** angiosperm is *Wolffia*. The plant body of *Wolffia* consists of tiny flat oval green stem (phylloclade) having a few small roots. The plants are about 1 mm in diameter and found free floating in aquatic habitats like ponds, etc.

(2) **The tallest** angiosperm is *Eucalyptus*. Their trees may attain a height upto 100 meters or more.

(3) **Banyan** (*Ficus bengalensis*) tree covers a large area. Its slanting aerial branches spread in all directions. The tree spreads with the help of prop or pillar roots.

### Longevity

Based on the duration of life, the plants are divided into following 4 categories :

(1) **Ephemerals** : This category includes the plants which live only for a few weeks because of a very short growing season. Such plants are found near deserts or in very cold countries. For example, *Arabidopsis* species have a life span of 20–28 days.

(2) **Annuals** : The plants of this category live and complete their life-cycle in a single favourable season. During this period, they grow in size, produce flowers, shed their seeds, undergo senescence and die. They pass the unfavourable period in the form of seeds. Many crop plants (e.g., wheat, rice, maize, etc.) are annuals. The smallest angiosperm – *Wolffia* is an aquatic annual.

(3) **Biennials** : The plants of this category complete their life-cycle in two favourable seasons (i.e., in two years). They grow vegetatively in the first season and produce flowers and set seeds in the next. Often they produce some storage organs, as in the sugar beet, where food is stored in their swollen roots.

(4) **Perennials** : Plants of this category live for more than two years. Generally they live for many years and bear the flowers and fruits during specific seasons. Some perennials continue their vegetative growth for several years and produce fruits and seeds only once in their life time, e.g., *Agave*, *Bamboos*, etc. They are called monocarpic. Others produce flowers and fruits every year after attaining a definite stage of maturity, e.g., *Mango*, *Lemon*, *Apple*, etc. Such plants are called polycarpic.

### Habit

Depending upon the habit of plants, the angiosperms belong to following categories :



(1) **Herb** : These are small, soft, non-woody plants without persistent parts aboveground. The height of plants usually reaches upto 1 m. The plants may be annual (*Brassica*), biennial (Sugar beet) or perennial (*Canna*). The perennial herbs usually possess underground rhizomes which form the new aerial shoots every year. The plants of banana are perennial herbs.

(2) **Shrubs** : These are woody plants of relatively low height (1-4 m). They typically branch at or near the base and do not have a main trunk, e.g., Rose. They are mostly perennial.

(3) **Trees** : These are perennial woody plants with one main trunk. The trunk may or may not be branched. These are of the following types :

(i) **Caudex** : The stem is unbranched and usually bears a crown of leaves at the apex. e.g., Date-palm.

(ii) **Excurrent** : The lower part of stem is thicker which gradually tapers above. Branches arise from the main stem in acropetal succession and plant appears conical e.g., *Pinus*.

(iii) **Deliquescent** : The apical bud of the main stem dies after some time and branches and sub-branches spread in different directions. e.g., *Tamarindus*, *Ficus*.

(4) **Culms** : In these plants, nodes and internodes are extremely clear. Internodes of such plants are usually hollow. These plants are grasses but cannot be considered as herb or shrub or tree. e.g., *Bambusa* (Bans).

The plants of Angiosperms divided into two major groups as – Dicotyledons and Monocotyledons

(1) **Dicotyledons** : They show following distinguished characteristics.

- (i) Tap roots found in the members of this group.
- (ii) The leaves in members of these class exhibit reticulate (net like) venation.
- (iii) The flowers are tetramerous or pentamerous having four or five members in the various floral whorls, respectively
- (iv) The vascular bundles arranged in a ring, numbering 2-6, open and with cambium.
- (v) The seeds of dicotyledons are with two cotyledons as the name indicate.

(2) **Monocotyledons** : They show following distinguished characteristics :

- (i) Adventitious roots found in the members of this group.
- (ii) The leaves are simple with parallel venation.
- (iii) The flowers are trimerous having three members in each floral whorl.
- (iv) The vascular bundles scattered in the ground tissue, many in number, closed and without cambium.
- (v) The seeds of monocotyledons are with one cotyledons as the name indicate. e.g., Cereals, bamboos, sugarcane, palms, banana, lillies and orchids.

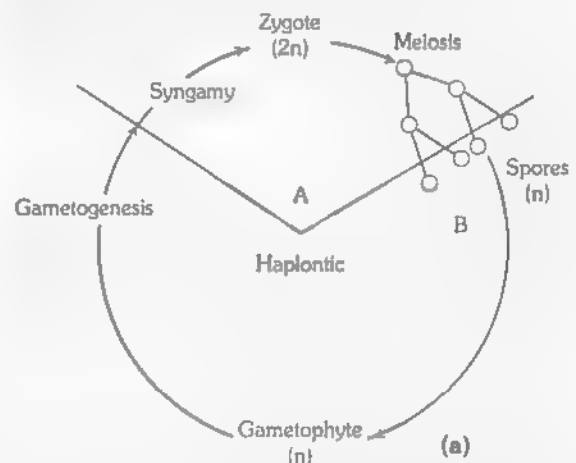
### Plant Life Cycles and Alternation of Generations

In plants, both haploid( $n$ ) and diploid( $2n$ ) cells can divide by mitosis. The haploid plant body produces gametes by mitosis (cell division). This plant body represents a gametophyte. After fertilisation the zygote also divides by mitosis to produce a diploid sporophytic plant body. Haploid spores are produced by this plant body by meiosis. These in turn, divide by mitosis to form a haploid

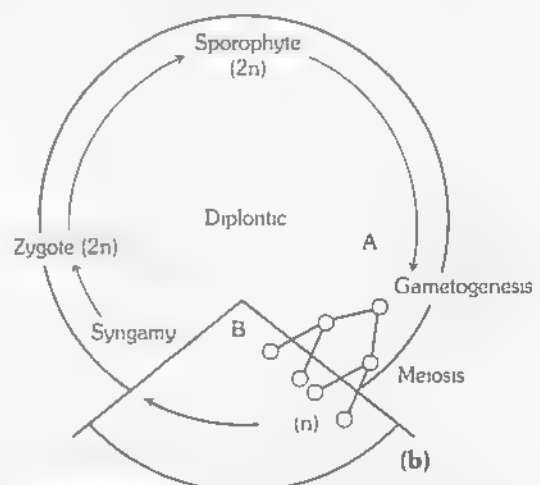
plant body once again. Thus during the life cycle of any sexually reproducing plant, there is an alternation of generations between gamete producing haploid gametophyte and spore producing diploid sporophyte.

The different patterns of life cycle in different plants are as follows :

(i) Haplontic life cycle is exhibited by many algae like *Spirogyra*, some *Chlamydomonas* species and *Volvox*. Sporophytic generation is represented only by the one-celled zygote. There are no free living sporophytes. Meiosis in the zygote results in the formation of haploid spores. The haploid spores divide mitotically and form the gametophyte. The dominant, photosynthetic phase in such plants is the free living gametophyte. This kind of life cycle is termed as **haplontic**.



(ii) On the other extreme, is the type wherein the diploid sporophyte is the dominant, photosynthetic independent phase of the plant. The gametophytic phase is represented by the single to few-celled haploid gametophyte. This kind of life cycle is termed as **diploptic**. All seed-bearing plants i.e., gymnosperms and angiosperms, follow this pattern.



(iii) Bryophytes and pteridophytes, interestingly, exhibit an intermediate condition (Haplo-diploptic) both phases are multicellular. However, they differ in their dominant phases.

A dominant, independent, photosynthetic, thalloid or erect phases is represented by a haploid gametophyte and it alternates with the short-lived multicellular sporophyte totally or partially dependent on the gametophyte for its anchorage and nutrition. All bryophytes represent this pattern.

The diploid sporophyte is represented by a dominant, independent, photosynthetic, vascular plant body. It alternates with multicellular, saprophytic/ autotrophic, independent but short-lived haploid gametophyte. Such a pattern is known as haplo-diplontic life cycle. All pteridophytes exhibit this pattern.

Interestingly, while most algal genera are haplontic some of them such as *Ectocarpus*, *Polysiphonia*, kelps are haplo-diplontic. *Fucus*, an alga is diplontic.

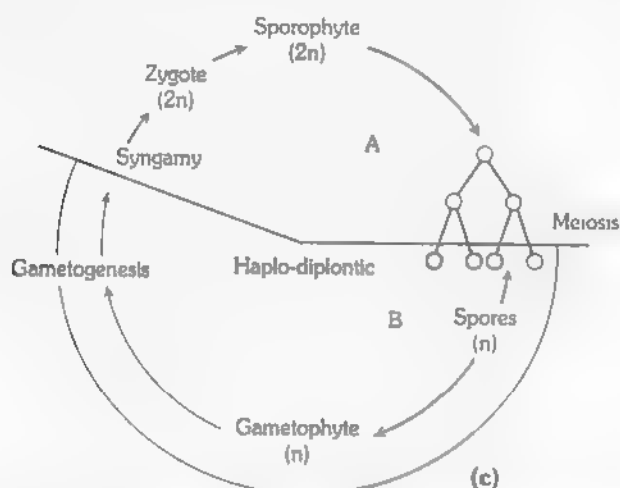


Fig : 1.6-37 Life cycle patterns : (a) Haplontic (b) Diplontic (c) Haplo-diplontic

## Tips & Tricks

✍ Father of Indian phycology : "M.O.P. Iyengar."

✍ Thallophytes : The term was coined by Endlicher (1863) for placing algae, fungi and bacteria in it. Plant body of thallophytes is called thallus. It does not show differentiation of stem, leaves and roots. An embryo stage is absent. They are most primitive members of plant kingdom.

✍ Algae : The term was coined by Linnaeus (1754) for hepaticae and others but was used for its present meaning by A.L. de Jussieu (1789).

✍ Multicellular algae are revolutionary older than land plants.

✍ The first algal antibiotics chlorococcin was extracted from *Chlorella*.

✍ *Cymbella* used as a bacterial filter.

✍ Bryophytes : The term coined by Robert Braun (1864). Bryophytes are nonvascular plants with multicellular sexorgans.

✍ Bryology : The science dealing with bryophytes. S.R. Kashyap is father of Indian Bryology.

✍ Sporogonium : Sporophyte of Bryophytes which is parasitic over gametophytic plant body and its mainly meant for producing meiospores.

✍ Erect gametophyte of bryophyte is called gametophore.

✍ A capsule of *Marchantia* forms about 3,000,000 spores.

✍ Smallest bryophyte is *Zoopsis*.

✍ Tallest bryophytes is *Dawsonia*.

✍ Tracheophytes : Sinnott (1935) coined the term to include vascular plants. (Pteridophytes and seed plants).

✍ Elaters : Elongated structures which help in spore dispersal.

✍ Cormophytes : Plants with distinction of stem, leaves and roots.

✍ Rudimentary seed habit occurs in *Selaginella*.

✍ *Acrostichum aureum* is a halophyte.

✍ *Marsilea* occurs as terrestrial, amphibious as well as aquatic plant.

✍ *Salvinia* is an aquatic pteridophyte weed.

✍ *Equisetum* is commonly known as Horse tails or Scouring rushes. A few species of *Equisetum* contain gold.

✍ *Lycopodium* is commonly known as club moss.

✍ Psilophytes (*Cooksonia*, *Rhynia* etc.) primitive pteridophytes of Silurian and Devonian period.

✍ *Chondrus* (Irish moss) is used in the preparation of various pharmaceuticals including laxatives and cosmetics.

✍ Vessels are major water conducting cell in angiosperm.

✍ The primitive haplocheilic type of stomata are found in *Cycas*, *Pinus*, *Ginkgo*, *Ephedra* etc.

✍ *Ophioglossum* (Adder's tongue fern) has maximum number of chromosomes ( $2n = 1262$ ) in plant kingdom.

✍ The vascular supply given for a leaf from the main stele is called leaf trace

✍ The vascular supply given out for a branch from main stele is called 'branch trace'.

✍ Sperms of *Cycas revoluta* are largest in the plant kingdom and measure about 200 to 300 $\mu$  wide.

✍ In gymnosperm endosperm is haploid and develops before fertilization

✍ The only gymnosperms showing limited growth is *Welwitschia* (45 cm tall).

✍ Embryosac of gymnosperm is haploid.

✍ In gymnosperm the arrangement of megaspore tetrad is linear.

✍ Sulphur shower is due to pollen of *Pinus/cedrus*.

- ✎ Bamboo or Agave are monocarpic perennial plants.
- ✎ Vessels are major water conducting cell in angiosperm.
- ✎ Double fertilization is a unique character of angiosperm.
- ✎ Anthophytes : Plants with flower/ flowering plants.
- ✎ Marine angiosperm : *Zostera*, *Thalassia*.
- ✎ National tree : *Ficus bengalensis* (Banyan).
- ✎ *Takakia* is a bryophyte without rhizoids. It bears mucilage hairs for water conduction.
- ✎ *Cereus giganteus* is largest cactus of 52 feet height.
- ✎ F.E. Fritsch (1935) divided algae into eleven classes mainly on the basis of pigmentation, reserve food and flagellation thallus structure, modes of reproduction and life cycles.
- ✎ Therophytes plants are those which survive in winter as a seed and complete their life cycle between the spring and autumn.
- ✎ In ferns, leaves are photosynthetic as well as reproductive in function.
- ✎ Sperms of *Cycas* and *Ginkgo* are motile and multiciliated.
- ✎ *Salvinia* is an aquatic weed and called sorrow of Kashmir.



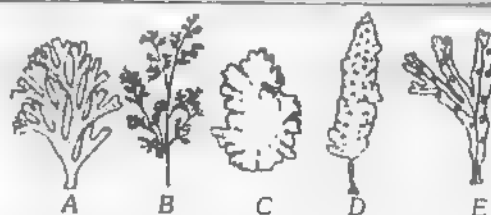
## Ordinary Thinking

### Objective Questions

#### Algae (General)

1. Who is regarded as the "Father of Indian Phycology" [BHU 1999]
  - (a) Prof. M.O.P. Iyenger (b) Prof. J.N. Mishra
  - (c) Prof. R.R. Mishra (d) Prof. R.N. Singh
2. Phycology is the study of [AMU (Med.) 1998, 2005; KCET 2002; Odisha JEE 2005; RPMT 2006]
  - (a) Algae (b) Fungi
  - (c) Bacteria (d) All the above
3. Who is popularly known as the "Father of Phycology"
  - (a) Fritsch (b) Papenfus
  - (c) Smith (d) Morris
4. Group of algae in which sexual reproduction is absent [Odisha JEE 2008]
  - (a) Cyanophyceae (b) Bacillariophyceae
  - (c) Chlorophyceae (d) None of these
5. Mannitol (sugar alcohol) is the stored food in [CBSE PMT 2009; WB JEE 2011]
  - (a) *Chara* (b) *Porphyra*
  - (c) *Fucus* (d) *Gracilaria*
6. Red tide is caused by [AFMC 2008]
  - (a) *Noctiluca* (b) *Gymnodinium*
  - (c) *Gonyaulax* (d) All of these
7. Agar-Agar is obtained from [CPMT 1996, 98, 2009; AFMC 1997; KCET 2000; BHU 2006; Kerala PMT 2007; Odisha JEE 2009; MP PMT 2013]
  - (a) *Gigartina* (b) *Gelidium*
  - (c) *Gracilaria* (d) All the above
8. Algae have cell wall made up of [NCERT; CBSE PMT (Pre.) 2010]
  - (a) Cellulose, hemicellulose and pectins
  - (b) Cellulose, galactans and mannans
  - (c) Hemicellulose, pectins and proteins
  - (d) Pectins, cellulose and proteins
9. Consider the following statements regarding the major pigments and stored food in the different groups of algae and select the correct options given
  - A. In chlorophyceae the stored food material is starch and the major pigments are chlorophyll-*a* and *d*
  - B. In phaeophyceae, laminarin is the stored food and major pigments are chlorophyll-*a* and *b*
  - C. In rhodophyceae, floridean starch is the stored food and the major pigments are chlorophyll-*a*, *d* and phycoerythrin
 [Kerala PMT 2008; AMU (Med.) 2012]
  - (a) A is correct, but B and C are wrong
  - (b) A and B are correct, but C is wrong
  - (c) A and C are correct, but B is wrong
  - (d) B is correct, but A and C are wrong
  - (e) C is correct, but A and B are wrong
10. In which of the following, all listed genera belong to the same class of algae [DUMET 2009]
  - (a) *Chara*, *Fucus*, *Polysiphonia*
  - (b) *Volvox*, *Spirogyra*, *Chlamydomonas*
  - (c) *Porphyra*, *Ectocarpus*, *Ulothrix*
  - (d) *Sargassum*, *Laminaria*, *Gracilaria*
11. External fertilization occurs in majority of [DUMET 2009]
  - (a) Algae (b) Fungi
  - (c) Liverworts (d) Mosses
12. Which of the following occurs both in fresh as well as in marine water [BHU 2008]
  - (a) *Oedogonium* (b) *Cladophora*
  - (c) *Spirogyra* (d) None of these
13. Both chlorophyll *a* and *b* are present in [AFMC 2009]
  - (a) Rhodophyceae (b) Phaeophyceae
  - (c) Chlorophyceae (d) None of these
14. Yellow-green pigment is found in [CPMT 2009]
  - (a) Xanthophyta (b) Chlorophyta
  - (c) Phaeophyta (d) Rhodophyta
15. If you are asked to classify the various algae into distinct groups, which of the following characters you should choose [CBSE PMT 2007]
  - (a) Types of pigments present in the cell
  - (b) Nature of stored food materials in the cell
  - (c) Structural organization of thallus
  - (d) Chemical composition of the cell wall
16. Which one of the following statements is wrong [AIPMT (Cancelled) 2015]
  - (a) Agar-agar is obtained from *Gelidium* and *Gracilaria*
  - (b) *Chlorella* and *Spirulina* are used as space food
  - (c) Mannitol is stored food in Rhodophyceae
  - (d) Algin and carragen are products of algae
17. Which one is a parasitic algae [CBSE PMT 2001; BHU 2001, 04; BVP 2002; RPMT 2006]
  - (a) *Vaucheria* (b) *Polysiphonia*
  - (c) *Cephaleuros* (d) *Batrachospermum*
18. Incorrect character of brown algae is [DPMT 2007]
  - (a) Presence of chl *a* and *b*
  - (b) It remain attached to substratum
  - (c) Presence of chl *a* and *c*
  - (d) Presence of fucoxanthin
19. Which of the following is a flagellated alga [HP PMT 2005]
  - (a) *Chlamydomonas* (b) *Ulothrix*
  - (c) *Spirogyra* (d) *Acetabularia*

20. Algae which form motile colony is [Odisha JEE 2005]  
 (a) *Volvox* (b) *Nostoc*  
 (c) *Spirogyra* (d) *Chlamydomonas*
21. Sporophytic generation is represented by zygote only in [CBSE PMT 1992]  
 (a) *Funaria* (b) *Chlamydomonas*  
 (c) *Pinus* (d) *Selaginella*
22. In biotechnological studies, the alga that is exploited as a rich source of protein is [AIIMS 2003, 08; Odisha JEE 2009]  
 (a) *Spirogyra* (b) *Spirulina*  
 (c) *Chlamydomonas* (d) *Scytonema*
23. More than one pyrenoid are present in  
 (a) *Ulothrix* (b) *Spirogyra*  
 (c) *Oedogonium* (d) All the above
24. True nucleus is absent in [AIPMT (Cancelled) 2015]  
 (a) *Mucor* (b) *Vaucheria*  
 (c) *Volvox* (d) *Anabaena*
25. Which one of the following statements concerning the algae is wrong  
 (a) Most algae are photosynthetic  
 (b) Algae can be classified according to their pigments  
 (c) All algae are filamentous  
 (d) *Spirogyra* does not produce zoospores
26. Consider the following statements with respect to algae  
 A. Fusion between one large, non-motile female gamete and a smaller, motile male gamete is termed as oogamous  
 B. Fusion of two gametes dissimilar in size is termed as isogamous  
 C. Fusion of two gametes similar in size is called anisogamous  
 D. In chlorophyceae the major pigments are chlorophyll a and b, and the food is stored as starch  
 E. In rhodophyceae the major pigments are chlorophyll a and d, and the food is stored as mannitol  
 Of the above statements [Kerala PMT 2012]  
 (a) A and E alone are correct  
 (b) C and E alone are correct  
 (c) A and B alone are correct  
 (d) A and D alone are correct  
 (e) B and D alone are correct
27. Which of the following is not correctly matched [Kerala PMT 2006]  
 (a) *Chlamydomonas* – Unicellular flagellated  
 (b) *Laminaria* – Flattened leaf like thallus  
 (c) *Chlorella* – Unicellular non-flagellated  
 (d) *Spirogyra* – Filamentous structure  
 (e) *Volvox* – Colonial form non-flagellated
28. Algae are important, we should study algae because  
 (a) They are good organisms to experiment with  
 (b) They can be grown in large tank cultures  
 (c) They may form important constituent of human food (diet) in future  
 (d) They produce oxygen and organic acids

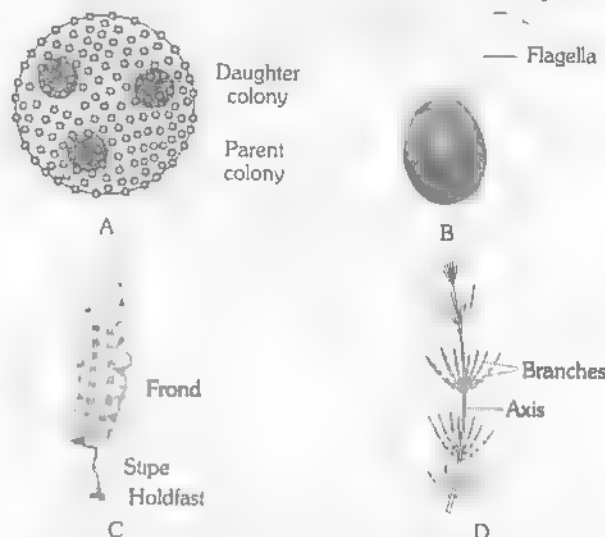


In the diagram given above, some of the algae have been labelled as 'A', 'B', 'C', 'D' and 'E'. These algae are respectively identified as [NCERT; Kerala PMT 2010]

- (a) *Dictyota*, *Polysiphonia*, *Porphyra*, *Fucus* and *Laminaria*  
 (b) *Porphyra*, *Dictyota*, *Laminaria*, *Fucus*, and *Polysiphonia*  
 (c) *Dictyota*, *Polysiphonia*, *Porphyra*, *Laminaria* and *Fucus*  
 (d) *Fucus*, *Porphyra*, *Dictyota*, *Polysiphonia*, and *Laminaria*  
 (e) *Laminaria*, *Polysiphonia*, *Porphyra*, *Dictyota* and *Fucus*
30. Comparable to angiosperms, which of the following algae exhibits diplontic life cycle [DUMET 2010; Kerala PMT 2010]  
 (a) *Spirogyra* (b) *Ectocarpus*  
 (c) *Polysiphonia* (d) *Fucus*
31. Choose the correct order of colours with respect to pigments, chlorophyll, phycoerythrin and fucoxanthin [CBSE PMT 1997; MP PMT 2005; Kerala PMT 2012]  
 (a) Green, red and brown  
 (b) Brown, green and red  
 (c) Red, green and brown  
 (d) Green, brown and red  
 (e) Brown, red and green
32. In the Chlorophyta, the reserve food of protein surrounded by starch, form a compact body termed [JIPMER 1993]  
 (a) Paramylum (b) Pyrenoid  
 (c) Volutin (d) Eye spot
33. Algae are in the same major group of plants as are the [CBSE PMT 1993]  
 (a) Mosses (b) Liverworts  
 (c) Fungi (d) Ferns
34. An alga which can be employed as food for human being is [CMC Vellore 1993; CBSE PMT 1997, 2014; BVP 2001, 04; CPMT 2004, 09; Kerala PMT 2012]  
 (a) *Chlorella* (b) *Spirogyra*  
 (c) *Oscillatoria* (d) *Ulothrix*
35. Which of the following is a character of rhodophyceae [Kerala PMT 2012]  
 (a) Major pigments are chlorophyll a and chlorophyll-b  
 (b) Commonly called brown algae  
 (c) Stored food materials are mannitol and laminarin  
 (d) Flagellum is absent  
 (e) Cell wall contains cellulose and algin
36. Non motile, greatly thickened asexual spore in *Chlamydomonas* is known as [Odisha JEE 2010]  
 (a) Zoospore (b) Akinete  
 (c) Hypnospor (d) Endospores
37. Isomorphic alternation of generations is found in [MP PMT 2010]  
 (a) *Oedogonium* (b) *Chara*  
 (c) *Vaucheria* (d) *Ectocarpus*

38. Palmella stage is produced  
(a) In rainy season  
(b) During unfavourable conditions  
(c) During favourable conditions  
(d) None of the above
39. All cells of sex organs are formed gametes in [RPMT 1995]  
(a) Algae (b) Bryophyta  
(c) Pteridophyta (d) Gymnosperm
40. Pyrenoids are made up of [NCERT; CBSE PMT 1995; RPMT 1995]  
(a) Core of starch surrounded by sheath of protein  
(b) Core of protein surrounded by fatty sheath  
(c) Proteinaceous centre and starchy sheath  
(d) Core of nucleic acid surrounded by protein sheath
41. Floridean starch is found in [BHU 1995; Odisha JEE 2011]  
(a) Chlorophyceae (b) Rhodophyceae  
(c) Myxophyceae (d) Cyanophages
42. Pyrenoids are characteristically found in the chloroplast of [MP PMT 1995]  
(a) Fungi (b) Algae  
(c) Pteridophytes (d) Angiosperms
43. The giant algae or sea weeds belong to class [Bihar MDAT 1995]  
(a) Phaeophyceae (b) Rhodophyceae  
(c) Chlorophyceae (d) Xanthophyceae
44. Most important alga in research centres is [CPMT 1996; RPMT 2006]  
(a) Mycoplasma (b) Spirogyra  
(c) Chlorella (d) Blue-green algae
45. Alginic acid is obtained from [HP PMT 2005; CPMT 2010]  
(a) Red algae (b) Green algae  
(c) Diatoms (d) Brown algae
46. Algae differ from Bryophyta in possessing [MP PMT 1998]  
(a) Naked sex organs  
(b) Sex organs covered with sterile covering  
(c) Chlorophylls  $\alpha$  and  $\beta$   
(d) Aerobic respiration
47. Red rust of tea is caused by [CPMT 1999; JIPMER 2001; BHU 2003]  
(a) *Cephaleuros* (b) *Synchytrium*  
(c) *Mucor* (d) *Fusarium*
48. In which of the following algal classes the starch and oil are present [CPMT 1998]  
(a) Chlorophyceae (b) Phaeophyceae  
(c) Rhodophyceae (d) Xanthophyceae
49. Which of the following pigments is present in all algae [CPMT 1998; J & K CET 2002]  
(a) Chlorophyll- $a$  (b) Chlorophyll- $b$   
(c) Chlorophyll- $c$  (d) Chlorophyll- $d$
50. Select the correct match from the options given below
- |     |               |   |                    |
|-----|---------------|---|--------------------|
| (A) | Phaeophyceae  | - | Mannitol           |
| (B) | Rhodophyceae  | - | Dictyota           |
| (C) | Chlorophyceae | - | Non-motile gametes |
| (D) | Rhodophyceae  | - | $r$ -Phycoerythrin |
- [Kerala PMT 2011; J & K CET 2012]  
(a) A, B and C (b) B, C and D  
(c) A and C (d) C and D  
(e) A and D
51. The element present in thyroxine is obtained from [CPMT 2000]  
Or  
Iodine is found in [Odisha JEE 2011]  
(a) *Laminaria* (b) *Polysiphonia*  
(c) *Porphyra* (d) *Gelidium*
52. Which of the following is obtained from algae [CBSE PMT 2000]  
(a) Wax (b) Butter  
(c) Chocolate (d) Carragenin
53. Marine algae flourished well during which period [CBSE PMT 2001]  
(a) Triassic (b) Devonian  
(c) Permian (d) Ordovician
54. Stomata are not found in [MP PMT 2001]  
(a) Algae (b) Mosses  
(c) Ferns (d) Gymnosperm
55. Smallest plant which contain green pigment such as higher green plant is [CPMT 2002; RPMT 2005]  
(a) Schizomycetes (b) Rhodophyceae  
(c) Chlorophyceae (d) Phaeophyceae
56. *Chlamydomonas* does not occur in [CPMT 2002; RPMT 2005]  
(a) Fresh water (b) Pond and lake  
(c) River (d) Ocean
57. Sexual reproduction in algae results in the formation of [DPMT 2003; BVP 2004]  
(a) Oospore (b) Zoospore  
(c) Zygote (d) Zygospor
58. *Macrocystis* is a [CPMT 2010]  
(a) Red algae (b) Fungi  
(c) Bryophyta (d) Brown algae
59. Which of the following form contain algae [BHU 2005]  
(a) *Equisetum* (b) *Selaginella*  
(c) *Marsilea* (d) None of these
60. Zygotic meiosis is characteristic of [J & K CET 2005; NEET 2017]  
(a) *Marchantia* (b) *Fucus*  
(c) *Funnaria* (d) *Chlamydomonas*
61. Reserve food material of algae is [Bihar CECE 2005, 06]  
(a) Starch (b) Glycogen  
(c) Fat (d) Sugar
62. Meiotic division in zygote takes place in [RPMT 1995]  
(a) Thallophyta (b) Angiosperms  
(c) Gymnosperms (d) Pteridophyta
63. Thallophyta includes [CPMT 1994; JIPMER 2000]  
(a) Fungi and bryophyta  
(b) Algae and bryophyta  
(c) Algae, fungi and bryophyta  
(d) Algae and fungi
64. Sea weeds are important source of [AFMC 2004]  
(a) Chlorine (b) Fluorine  
(c) Iodine (d) Bromine
65. The thallus of *Volvox* is called [Pb. PMT 2004]  
(a) Trichome (b) Coenobium  
(c) Coenocyte (d) Parenchymatous

66. *Batrachospermum* is found in [MHCET 2001]  
 (a) Marine water (b) Fresh water  
 (c) Tree (d) Arctic zone
67. In oogamy, fertilization involves [CBSE PMT 2004]  
 (a) A large non-motile female gamete and a small non-motile male gamete  
 (b) A large motile female gamete and a small non-motile male gamete  
 (c) A small non-motile female gamete and a large motile male gamete  
 (d) A large non-motile female gamete and a small motile male gamete
68. Agar agar is obtained from [BVP 2001, 02; AFMC 2004; CPMT 2004]  
 (a) Green algae (b) Red algae  
 (c) Brown algae (d) Blue green algae
69. Agranal chloroplast are found in [DPMT 2004]  
 (a) Bryophytes (b) Gymnosperms  
 (c) Green algae (d) Angiosperms
70. Algae attached to stone is called [Odisha JEE 2004]  
 (a) Epilithic (b) Epifolic  
 (c) Coenolithic (d) None of these
71. Monoecious plant of *Chara* shows occurrence of [NEET 2013]  
 (a) Upper oogonium and lower antheridium on the same plant  
 (b) Antheridiophore and archegoniophore on the same plant  
 (c) Stamen and carpel on the same plant  
 (d) Upper antheridium and lower oogonium on the same plant
72. Select the wrong statement [NCERT; NEET 2013]  
 (a) *Chlamydomonas* exhibits both isogamy and anisogamy and *Fucus* shows oogamy  
 (b) Isogametes are similar in structure, function and behaviour  
 (c) Anisogametes differ either in structure, function or behaviour  
 (d) In Oomycetes female gamete is smaller and motile, while male gamete is larger and non-motile
73. Which of the following is **not** correctly matched for the organism and its cell wall degrading enzyme [NEET 2013]  
 (a) Fungi – Chitinase (b) Bacteria – Lysozyme  
 (c) Plant cells – Cellulase (d) Algae – Methylase
74. Syngamy can occur outside the body of the organism in [NEET (Karnataka) 2013]  
 (a) Mosses (b) Algae  
 (c) Ferns (d) Fungi
75. Observe the diagram A, B, C, D. In which one of the four options all the items are correct [NCERT]



	A	B	C	D
(a)	<i>Chlamydomonas</i>	<i>Chara</i>	<i>Laminaria</i>	<i>Volvox</i>
(b)	<i>Laminaria</i>	<i>Volvox</i>	<i>Chlamydomonas</i>	<i>Chara</i>
(c)	<i>Chara</i>	<i>Laminaria</i>	<i>Volvox</i>	<i>Chlamydomonas</i>
(d)	<i>Volvox</i>	<i>Chlamydomonas</i>	<i>Laminaria</i>	<i>Chara</i>

76. Which one of the following is wrong about *Chara* [CBSE PMT 2014]  
 (a) Upper antheridium and lower oogonium  
 (b) Globule is male reproductive structure  
 (c) Upper oogonium and lower round antheridium  
 (d) Globule and nucule present on the same plant
77. Male gametes are flagellated in [AIPMT (Cancelled) 2015]  
 (a) *Anabaena* (b) *Ectocarpus*  
 (c) *Spirogyra* (d) *Polysiphonia*
78. Which one of the following statements is wrong [NEET (Phase-II) 2016]  
 (a) *Laminaria* and *Sargassum* are used as food  
 (b) Algae increase the level of dissolved oxygen in the immediate environment  
 (c) Algin is obtained from red algae, and corragenan from brown algae  
 (d) Agar-agar is obtained from *Gelidium* and *Gracilaria*
79. An example of colonial alga is [NEET 2017]  
 (a) *Chlorella* (b) *Volvox*  
 (c) *Ulothrix* (d) *Spirogyra*

### Spirogyra and Ulothrix

1. Two adjacent filaments of *Spirogyra affinis* having 10 cells each are participating in reproduction. How many new *Spirogyra* plants are produced during sexual reproduction [EAMCET 2009]  
 (a) 5 (b) 10  
 (c) 20 (d) 40
2. *Spirogyra* increases its body length by the division of [AFMC 2001]  
 (a) The apical cell  
 (b) The basal cell  
 (c) Every cell of the body  
 (d) Accumulation of food in his body

3. Sexual reproduction in *Spirogyra* involves fusion of [MP PMT 1994; BVP 2003]
  - (a) Two similar motile gametes
  - (b) Two similar non-motile gametes but physiological dissimilar
  - (c) One motile and one non-motile gametes
  - (d) Two dissimilar motile gametes
4. *Spirogyra* is a [CPMT 1996]
  - (a) Fresh water and free floating alga
  - (b) Marine and free floating alga
  - (c) Fresh water and locomotory alga
  - (d) None of the above
5. Zygospore of *Spirogyra* produces [CBSE PMT 1993]
  - (a) 2 zoospores
  - (b) 4 zoospores
  - (c) 2-4 zoospores
  - (d) None of the above
6. On germination each zygospore of *Spirogyra* gives rise to
  - (a) Four plants
  - (b) Three plants
  - (c) Two plants
  - (d) One plant
7. Pond silk is the common name of [Kerala CET 2003]
  - (a) *Ulothrix*
  - (b) *Spirogyra*
  - (c) *Vaucheria*
  - (d) *Oedogonium*
8. In *Ulothrix*, sexual reproduction is by [Bihar PMT 1994; CBSE PMT 1997]
  - (a) Isogamy
  - (b) Anisogamy
  - (c) Oogamy
  - (d) Conjugation
9. In *Spirogyra* lateral conjugation takes place in the cells of [Odisha JEE 2010]
  - (a) Same filament
  - (b) Two filaments of same species
  - (c) Two filaments of different species
  - (d) Both (a) and (b)
10. In *Spirogyra* during the germination of zygospore how many haploid nuclei take part [Bihar MDAT 1995; CPMT 2001; AIIMS 2001]
  - (a) One
  - (b) Two
  - (c) Three
  - (d) All four
11. Sexual reproduction in which cells of two different *Spirogyra* filaments conjugate is known as [KCET 1998; CPMT 1999]
  - (a) Lateral conjugation
  - (b) Scalariform conjugation
  - (c) Parthenocarp
  - (d) Azygospory
12. The product of conjugation of *Spirogyra* is called [CBSE PMT 2000; CPMT 2000]
  - (a) Zoospore
  - (b) Akinete
  - (c) Chlamydospore
  - (d) Zygospore
13. *Spirogyra* differs from moss protonema in having
  - (a) Pyrenoid
  - (b) Branched filament
  - (c) Discoid chloroplast
  - (d) Rhizoidal branches
14. The sexual reproduction in *Spirogyra* is
  - (a) Oogamous
  - (b) Anisogamous
  - (c) Cleistogamous
  - (d) None of the above
15. Sexual reproduction in *Spirogyra* can be described as [MP PMT 1995, 98, 2001; BHU 2002]
  - (a) Morphological anisogamy and physiological isogamy
  - (b) Morphological as well as physiological isogamy
  - (c) Morphological as well as physiological anisogamy
  - (d) Morphological isogamy and physiological anisogamy
16. When three *Spirogyra* filaments are participating in conjugation, the possibilities are that
  - (a) The middle one may be female and outer ones are male
  - (b) The middle one may be male and outer ones are female
  - (c) Both (a) and (b)
  - (d) None of the above
17. In *Spirogyra*, ladder like structure is formed in
  - (a) Lateral conjugation
  - (b) Fragmentation
  - (c) Palmella stage
  - (d) Scalariform conjugation
18. In *Spirogyra* sometimes the gametes behave directly as zygospores without fusion. Such reproductive bodies are called [AIIMS 1992]
  - (a) Azygospores
  - (b) Hypnospores
  - (c) Zygospores
  - (d) Aplanospores
19. The cell wall of *Spirogyra* is made up of [MP PMT 1996]
  - (a) Cellulose
  - (b) Pectin
  - (c) Lignin
  - (d) Chitin
20. Zoospores are absent in [Odisha JEE 2012]
  - (a) *Vaucheria*
  - (b) *Spirogyra*
  - (c) *Cladophora*
  - (d) *Chlamydomonas*
21. In *Spirogyra* [Odisha JEE 2002]
  - (a) The filaments showing scalariform conjugation are homothallic
  - (b) The filaments showing lateral conjugation are homothallic
  - (c) The filaments showing lateral conjugation are heterothallic
  - (d) Asexual reproduction occurs by zoospores
22. Which one of the following is an example of chlorophyllous thallophyte [KCET 2011]
  - (a) *Volvariella*
  - (b) *Spirogyra*
  - (c) *Nephrolepis*
  - (d) *Gnetum*
23. Which is correct statement for *Ulothrix* [CBSE PMT 1998]
  - (a) Filamentous alga with flagellated reproductive stages
  - (b) Filamentous alga with nonflagellated reproductive stages
  - (c) Membranous alga producing zoospores
  - (d) Nonmotile colonial alga lacking reproductive stages
24. A cell of *Ulothrix* has chloroplasts [RPMT 1995, 96]
  - (a) 1
  - (b) 2
  - (c) 3
  - (d) 4
25. Pigments present in *Ulothrix* are [RPMT 2002]
  - (a) Chl. a, Chl b and phycocyanin
  - (b) Chl. a, Chl c, phycocyanin and fucoxanthin
  - (c) Chl. a, Chl b, carotenes and xanthophylls
  - (d) Chl. a and fucoxanthin
26. Which of the following shows aplanetism [BHU 2012]
  - (a) *Ulothrix*
  - (b) *Spirogyra*
  - (c) *Saprolegnia*
  - (d) *Chlamydomonas*
27. Cells of *Ulothrix* are
  - (a) Round
  - (b) Spherical
  - (c) Cylindrical
  - (d) Rectangular
28. *Spirogyra* differs from *Mucor* in having [CPMT 1994]
  - (a) Uninucleate gametangia
  - (b) Multicellular gametes
  - (c) Anisogamete
  - (d) Sexual reproduction
29. Meiosis in *Ulothrix* takes place during [CBSE PMT 1993; CPMT 1995; MHCET 2001; MP PMT 2002; AIIMS 2004]
  - (a) Zoospore formation
  - (b) Gamete formation
  - (c) Zygote germination
  - (d) Zoospore germination
30. The chloroplast in *Spirogyra* is [Kashmir MEE 1995; BVP 2003]
  - (a) Spiral band shaped and wavy margin
  - (b) Cup shaped and smooth margin
  - (c) Star shaped and wavy margin
  - (d) Girdle shaped and smooth margin

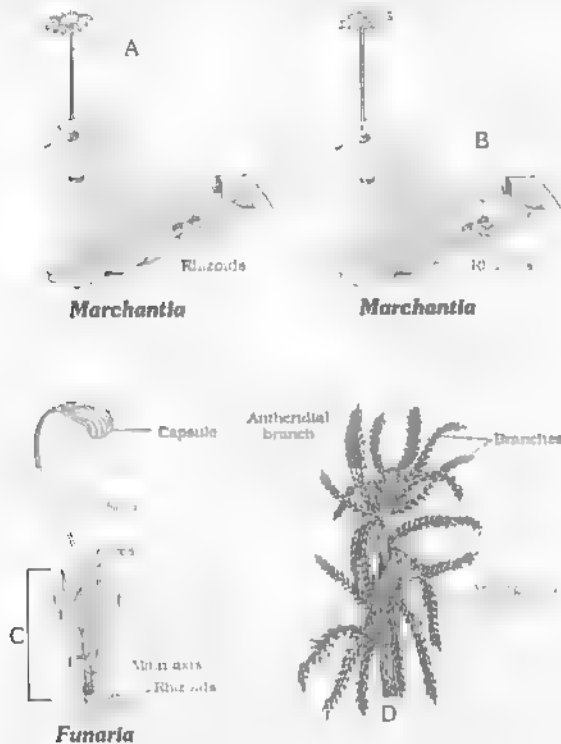
31. Which one of the following shows isogamy with non-flagellated gametes [NEET 2013; CBSE PMT 2014]  
 (a) *Ulothrix* (b) *Spirogyra*  
 (c) *Sargassum* (d) *Ectocarpus*
32. In *Ulothrix*, the cell contains [AFMC 1994]  
 (a) A chloroplast with many pyrenoids  
 (b) A chloroplast with few pyrenoids  
 (c) A few chloroplasts with few pyrenoids  
 (d) Many chloroplasts with few pyrenoids
33. Indian species of *Spirogyra* in which Prof. Iyengar discovered direct lateral conjugation is  
 (a) *Spirogyra sahnii* (b) *Spirogyra indica*  
 (c) *Spirogyra jogensis* (d) *Spirogyra karnatae*
34. *Ulothrix* is  
 (a) Attached unbranched filament  
 (b) Attached branched filament  
 (c) Colonial alga  
 (d) Free floating
35. A spore of *Spirogyra* sp. after resting period is [MP PMT 1997]  
 (a) Haploid (b) Diploid  
 (c) Aplanospore (d) Zygospore
36. Zygotic meiosis takes place in [MP PMT 1998]  
 (a) *Selaginella* (b) *Spirogyra*  
 (c) *Pinus* (d) *Brassica*
37. Which one of the following is wrongly matched [NEET (Karnataka) 2013]  
 (a) *Spirogyra* – Motile gametes  
 (b) *Sargassum* – Chlorophyll C  
 (c) Basidiomycetes – Puffballs  
 (d) *Nostoc* – Water blooms
38. *Spirogyra* has a [MP PMT 1999, 2002]  
 (a) Haplontic life cycle  
 (b) Diplontic life cycle  
 (c) Haplobiontic life cycle  
 (d) Diplobiontic life cycle
39. Chloroplast in *Ulothrix* is [RPMT 1999; Kerala PMT 2004]  
 (a) Reticulate (b) Cuplike  
 (c) Spiral (d) Girdle shaped
40. *Ulothrix* produces [BVP 2001]  
 (a) Isogametes (b) Anisogametes  
 (c) Ascospores (d) Heterogametes
41. Presence of basal rhizoidal cell in *Ulothrix* is an example of [RPMT 1998]  
 (a) Dead cell  
 (b) Vestigial cell  
 (c) Accessory cell  
 (d) Beginning of division of labour
42. Basal cell of *Ulothrix* is [JIPMER 1999]  
 (a) Antheridium (b) Meristematic  
 (c) Holdfast (d) Zoogonidium
43. Number of flagella present in the gametes of *Ulothrix* is  
 (a) Four (b) Three  
 (c) One (d) Two

## Bryophytes (General)

1. Which of these is mismatched [Kerala PMT 2006]  
 (a) Phaneros – Visible  
 (b) Kryptos – Concealed  
 (c) Gymmo – Naked  
 (d) Bryon – Liverworts  
 (e) Trachea – Windpipe
2. The largest bryophyte is  
 (a) *Funaria* (Moss) (b) *Marchantia*  
 (c) *Megaceros* (d) *Dowsonia*
3. Who amongst the following is regarded as the "Father of Indian Bryology" [CPMT 1998]  
 (a) Prof. K.C. Mehta (b) Prof. D.D. Pant  
 (c) Prof. S.R. Kashyap (d) Prof. P.N. Mehra
4. Bryophytes have probably evolved from [Odisha JEE 2008]  
 (a) Blue green algae (b) Green algae  
 (c) Blue algae (d) Red algae
5. Venter is the part of  
 (a) Sporogonium (b) Sporangium  
 (c) Antheridium (d) Archegonium
6. Choose the wrong pair [Kerala PMT 2008, 12]  
 (a) Hepaticopsida – *Marchantia*  
 (b) Lycopsidea – *Selaginella*  
 (c) Bryopsida – *Anthoceros*  
 (d) Pteropsida – *Dryopteris*  
 (e) Sphenopsida – *Equisetum*
7. In which of the following groups would you place a plant which produces spores and embryos but lacks seeds and vascular tissue  
 (a) Fungi (b) Bryophytes  
 (c) Pteridophytes (d) Gymnosperms
8. Bryophytes are of  
 (a) Great economic value  
 (b) No value at all  
 (c) Great ecological importance  
 (d) A lot of aesthetic value
9. Botanical name of peat moss is [NCERT; AFMC 2010]  
 Or  
 Which of the following is responsible for peat formation [CBSE PMT 2014]  
 (a) *Sphagnum* (b) *Funaria*  
 (c) *Anthoceros* (d) *Polytrichum*
10. Last stage of gametophytic generation is [RPMT 1995]  
 (a) Gametes (b) Zygote  
 (c) Spore mother cells (d) Spores
11. Which one of the following is true moss  
 (a) Club moss (b) Reindeer moss  
 (c) Irish moss (d) Bogg moss (*Sphagnum*)
12. Bryophytes differ from pteridophytes in [BHU 1995, 2000; AFMC 1995; CPMT 1996; MP PMT 2013]  
 (a) Swimming antherozoids  
 (b) An independent gametophyte  
 (c) Archegonia  
 (d) Lack of vascular tissue



13. Observe the diagrams (A - D) given below and select the right option in which all the four items A - D are correctly identified [NCERT; CBSE PMT (Mains) 2011]



	A	B	C	D
(a)	Antheridia	Archegonia	Gemma cup	Sphagnum
(b)	Archegonia	Antheridia	Gemma cup	Sphagnum
(c)	Archegoniophore	Gemma cup	Gametophyte	Sphagnum
(d)	Gemma cup	Archegoniophore	Sporophyte	Sphagnum

14. Elaters are present in sporogonium of [CMC Vellore 1993; AIIMS 2002]  
 (a) *Riccia* (b) *Marchantia*  
 (c) *Selaginella* (d) *Sphagnum*
15. Gametophytic generation is dominant in [NCERT; RPMT 1995; CPMT 1998; Pb. PMT 2000; KCET 2001, 11; Odisha JEE 2005]  
 (a) Pteridophyta (*Pteris*) (b) Bryophyta (*Riccia*)  
 (c) Angiosperms (*Rose*) (d) Gymnosperms (*Pinus*)
16. First land inhabiting plants are [CBSE PMT 1993; MP PMT 2004]  
 (a) Angiosperms (b) Gymnosperms  
 (c) Bryophytes (d) Pteridophytes
17. One of the following is of considerable economic importance [CBSE PMT 1993]  
 (a) *Riccia* (b) *Funaria*  
 (c) *Marchantia* (d) *Sphagnum*
18. Bryophytes can be separated from algae, because they [CBSE PMT 1997, 99]  
 (a) Are thalloid forms  
 (b) Have no conducting tissue  
 (c) Possess archegonia  
 (d) Contain chloroplast

19. Compared with the gametophytes of the bryophytes the gametophytes of vascular plants tend to be [CBSE PMT (Pre.) 2011]  
 (a) Smaller and to have smaller sex organs  
 (b) Smaller but to have larger sex organs  
 (c) Larger but to have smaller sex organs  
 (d) Larger and to have larger sex organs
20. Bryophytes resemble algae in the following aspects [KCET 2009]  
 (a) Filamentous body, presence of vascular tissues and autotrophic nutrition  
 (b) Differentiation of plant body into root, stem and leaves and autotrophic nutrition  
 (c) Thallus like plant body, presence of root and autotrophic nutrition  
 (d) Thallus-like plant body, lack of vascular tissues and autotrophic nutrition
21. Archegoniophore is present in [CBSE PMT (Pre.) 2011]  
 (a) *Funaria* (b) *Marchantia*  
 (c) *Chara* (d) *Adiantum*
22. The evidence for aquatic origin of bryophytes is [CPMT 1995, 2000; KCET 2000]  
 (a) Ciliated sperms (b) Green colour  
 (c) Protonema thread (d) Some are still aquatic
23. Saprophytic bryophyte is [MP PMT 2003]  
 (a) *Buxbaumia aphylla* (b) *Ricciocarpus natans*  
 (c) *Riccia fluitans* (d) *Radula sp*
24. Sporophyte dependent upon gametophyte is found in [BHU 1995]  
 (a) Algae (b) Fungi  
 (c) Bryophytes (d) Pteridophytes
25. Which place in India is called "The Golden Mine of Liverworts" [Kerala CET 2003]  
 (a) Eastern Himalayas (b) Western Himalayas  
 (c) Western Ghats (d) Eastern Ghats
26. Bryophytes comprise [CBSE PMT 1999; MP PMT 2013]  
 (a) Sporophyte is of longer duration  
 (b) Dominant phase of sporophyte which is parasitic  
 (c) Dominant phase of gametophyte which produces spores  
 (d) Small sporophyte phase and generally parasitic on gametophyte
27. Which of the following is true about bryophytes [CBSE PMT 1999; BHU 2004]  
 (a) They possess archegonia (b) They contain chloroplast  
 (c) They are thalloid (d) All of these
28. Dichotomous branching is found in [CBSE PMT 1999]  
 (a) Fern (b) *Funaria*  
 (c) Liverworts (d) *Polytrichum*
29. Bryophytes are dependent on water because [CBSE PMT 1998; BHU 2012]  
 (a) Archegonium has to remain filled with water for fertilization  
 (b) Water is essential for fertilization for their homosporous nature  
 (c) Water is essential for their vegetative propagation  
 (d) The sperms can easily reach upto egg in the archegonium

30. What is incorrect for bryophytes [RPMT 1997]  
 (a) Vascular tissue lacking  
 (b) Independent sporophyte absent  
 (c) Gametophyte reduced and dependent  
 (d) Asexual reproduction by zoospores absent
31. The term bryophyta was given by [Pb. PMT 2000]  
 (a) Darwin (b) Braun  
 (c) Aristotle (d) Galen
32. Which of the following is called amphibians of plant kingdom [AFMC 2009; Kerala PMT 2012]  
 (a) Bryophytes (b) Pteridophytes  
 (c) Gymnosperms (d) Algae
33. Female reproductive part of bryophytes is [MHCET 2000; BVP 2001; Odisha JEE 2004; PET (Pharmacy) 2013]  
 (a) Antheridium (b) Oogonium  
 (c) Archegonium (d) Sporangium
34. A bryophyte which harbours a nitrogen fixing blue-green alga in its thallus is [CPMT 2004]  
 (a) *Pogonatum* (b) *Riccia*  
 (c) *Marchantia* (d) *Anthoceros*
35. In bryophytes, which part of archegonium encloses egg [BVP 2000]  
 (a) Neck (b) Cover cell  
 (c) Venter (d) Neck canal cells
36. In Bryophyta the adult plant body is [Kerala PMT 2004]  
 (a) Sporophyte (b) Epiphyte  
 (c) Sporophyll (d) Gametophyte  
 (e) Antheridium
37. A bryophyte suddenly started reproducing parthenogenetically. The number of chromosomes of the second generation compared to parent plant will be [MHCET 2001]  
 (a) Same (b) One-half  
 (c) Double (d) Triple
38. Spore dissemination in some liverworts is aided by [CBSE PMT 2007]  
 (a) Elaters (b) Indusium  
 (c) Calyptra (d) Peristome teeth
39. Largest gametophyte is found in ..... [KCET 2004]  
 (a) Angiosperm (b) *Polytrichum*  
 (c) *Nephrolepis* (d) *Cycas*
40. In which of the following pyrenoids are present [RPMT 2006]  
 (a) *Marchantia* (b) *Riccia*  
 (c) *Anthoceros* (d) All of these
41. Have capacity of absorbing water, used to replace cotton and used as a fuel is [BHU 2005; AMU (Med.) 2009]  
 (a) *Marchantia* (b) *Riccia*  
 (c) *Sphagnum* (d) *Funaria*
42. Moss peat is used as a packing material for sending flowers and live plants to distant places because [CBSE PMT 2006]  
 (a) It reduces transpiration (b) It serves as a disinfectant  
 (c) It is easily available (d) It is hygroscopic
43. During development of embryo in archegonium of Bryophyta its posterior part form protective embryo cover which is called [RPMT 2006]  
 (a) Calyptra (b) Paraphysis  
 (c) Apophysis (d) Hypophysis
44. Which of the following is not a bryophyte [MP PMT 2010]  
 (a) *Pteris* (b) *Funaria*  
 (c) *Porella* (d) *Pellia*
45. Which of the following statements is/are incorrect regarding bryophytes [NCERT; Odisha JEE 2010]  
 (a) Zygote undergoes meiosis to produce sporophyte  
 (b) Zygote undergoes mitosis to form embryo proper  
 (c) Fertilization takes place in presence of water  
 (d) Sporophyte is parasitic over gametophyte
46. Male and female gametophytes are independent and free-living in [CBSE PMT (Pre.) 2010]  
 (a) *Sphagnum* (b) Mustard  
 (c) Castor (d) Pinus
47. The plant body is thalloid in [NEET (Karnataka) 2013]  
 (a) *Sphagnum* (b) *Salvinia*  
 (c) *Marchantia* (d) *Funaria*

### Funaria and Riccia

1. Primitive types of stomata are found in the [AIIMS 1998, 99; BHU 2006]  
 (a) Leaves of moss plants  
 (b) Axis of the moss plant  
 (c) Apophysis of capsule of moss  
 (d) All the above
2. Calyptra develops from [KCET 2000; BHU 2006; MP PMT 2009]  
 (a) Venter wall of archegonium  
 (b) Outgrowth of gametophyte  
 (c) Neck wall of archegonium  
 (d) Paraphysis of the archegonial branch
3. Protonema is [AIIMS 1993; BVP 2000; Kerala CET 2003; CPMT 2005]  
 (a) Fossil pteridophyte  
 (b) A part of the sporophyte of *Funaria*  
 (c) The juvenile phase of the moss gametophyte  
 (d) None of the above
4. In a moss the sporophyte [CBSE PMT 2006]  
 (a) Arises from a spore produced from the gametophyte  
 (b) Manufactures food for itself, as well as for the gametophyte  
 (c) Is partially parasitic on the gametophyte  
 (d) Produces gametes that give rise to the gametophyte
5. *Funaria* is attached to substratum by [CPMT 2005]  
 (a) Roots (b) Rhizoids  
 (c) Haustoria (d) Stem
6. The archegonia of *Funaria* is distinguished from that of *Pinus* by the structure of [MP PMT 2013]  
 (a) Long neck (b) Several neck canal cells  
 (c) Stalked venter (d) All of the above

7. In moss, reduction division takes place in
  - (a) Capsule (b) Archegonia
  - (c) Antheridium (d) At the tip of rhizoids
8. Which is not a part of moss capsule
  - (a) Peristome (b) Protonema
  - (c) Theca from operculum (d) Annulus
9. Life cycle of *Funaria* is not completed without water. Choose the correct statement [NCERT; CMC Vellore 1993]
  - (a) As *Funaria* is a bryophyte plant
  - (b) As branches will not develop
  - (c) As fertilization takes place in presence of water only
  - (d) As plant is delicate and will become dry and die without water
10. A feature common to gametophytes and sporophytes of mosses and ferns is
  - (a) Independent existence (b) Autotrophic nutrition
  - (c) Unbranched habit (d) Branched habit
11. If a moss protonema is developed from few cells of the moss capsule wall, then most probably it will be
  - (a) Haploid (b) Diploid
  - (c) Triploid (d) Polyploid
12. Protonema is found in the life cycle of [Kerala CET 2003; MP PMT 2009; CPMT 2010]
  - (a) *Spirogyra* (b) *Rhizopus*
  - (c) *Funaria* (d) *Escherichia*
13. Which one of the following is absent in sporophyte of *Funaria* [MP PMT 2000; AIIMS 2010]
  - (a) Foot (b) Seta
  - (c) Elaters (d) Columella
14. In moss capsule, dispersal of spores takes place through [CPMT 1995; MP PMT 2009]
  - (a) Peristome teeth (b) Annulus
  - (c) Calyptra (d) Operculum
15. The dehiscence of moss capsule takes place by rupture of
  - (a) Operculum (b) Peristome
  - (c) Annulus (d) Calyptra
16. In archegonium of moss (*Funaria*) plant, the number of neck canal cells is
  - (a) 2 (b) 3
  - (c) 5 (d) 6 to 18
17. *Funaria* gametophyte is [AIIMS 2001; MP PMT 2001, 04]
  - (a) Dioecious and autoecious
  - (b) Monoecious and autoecious
  - (c) Dioecious and heteroecious
  - (d) Monoecious and heteroecious
18. Acrocarpous, solitary sporangia are found in [Odisha JEE 2012]
  - (a) *Opuntia* (b) *Cycas*
  - (c) *Pinus* (d) *Funaria*
19. The sporophytic phase in *Funaria* is well developed and is composed of
  - (a) Foot, seta and capsule (b) Spore sac
  - (c) Capsule only (d) Foot and capsule
20. In moss, medulla has
  - (a) Endodermis (b) Hadrome
  - (c) Hypodermis (d) Piliferous layer
21. Vegetative reproduction in *Funaria* takes place by [Kashmir MEE 1995]
  - (a) Primary protonema (b) Gemmae
  - (c) Secondary protonema (d) All the above
22. The dominant phase in the life cycle of *Funaria* is
  - (a) Protonema (b) Leafy gametophyte
  - (c) Spore (d) Sporophyte
23. Apophysis in moss capsule is [BHU 1994]
  - (a) Upper part (b) Middle part
  - (c) Lower part (d) Fertile part
24. The peristome of *Funaria* has [MP PMT 1993; CPMT 1999; BHU 1999; BCECE 2005]
  - (a) 4 teeth in one ring (b) 32 teeth in 2 rings
  - (c) 16 teeth in one rings (d) 16 teeth in 2 rings
25. Where are the antheridia and archegonia situated in moss [AIIMS 2000]
  - (a) On the apex of leaves (b) In the axil of leaves
  - (c) On the apex of stem (d) On the base of stem
26. The antherozoids of *Funaria* are [CBSE PMT 1999]
  - (a) Aciliated (b) Biciliated
  - (c) Multiciliated (d) Monociliated
27. Largest gametophyte is found in [MP PMT 2011]
  - (a) *Funaria* (b) *Selaginella*
  - (c) *Pinus* (d) *Cycas*
28. *Funaria* has [MP PMT 1993; J & K CET 2002]
  - (a) Unicellular simple rhizoids
  - (b) Tuberculated rhizoids
  - (c) Distinct branched coenocytic rhizoids
  - (d) Multicellular, oblique septate rhizoids
29. The middle sterile portion in the capsule of moss (*Funaria*) is [RPMT 1997]
  - (a) Spore sac (b) Protonema
  - (c) Collumela (d) Apophysis
30. Female sex organ in *Funaria* is called [BHU 2000]
  - (a) Paraphysis (b) Oospores
  - (c) Archegonium (d) Artheridium
31. In *Funaria*, stomata are present on the [MP PMT 1996, 2000; CPMT 1996; CBSE PMT 2001; MHCET 2001]
  - (a) Leaf (b) Stem
  - (c) Upper part of capsule (d) Lower part of capsule
32. An archegonium of *Riccia* has [Bihar PMT 1994]
  - (a) 4 neck canal cells, 1 venter canal cell and one oosphere
  - (b) 4 neck canal cells, 2 venter canal cells one oosphere
  - (c) 4 neck canal cells, one venter canal cell and two oospheres
  - (d) 6 neck canal cells, 2 venter canal cells and one oosphere
33. Spores of *Riccia* are liberated by
  - (a) Peristome teeth and seta
  - (b) Shrinkage of annulus and explosion of capsule
  - (c) Death and decay of thallus and external pressure on calyptra
  - (d) Xerochasy of elaters

34. The sporophyte of *Funaria* begins development within  
[MP PMT 1998, 2002]  
(a) Antheridia (b) Capsule  
(c) Protonema (d) Archegonium
35. Rhizoids in *Riccia* are [RPMT 1995, 2002, 06]  
(a) Unicellular smooth-walled  
(b) Unicellular tuberculate  
(c) Both smooth-walled and tuberculate unicellular  
(d) Multicellular smooth-walled and tuberculate
36. Which of the following stage of *Funaria* is haploid  
[CPMT 1996]  
(a) Gametophyte (b) Sporophyte  
(c) Both (a) and (b) (d) None of these
37. In *Riccia* / *Marchantia* the rhizoids are  
(a) Branched unicellular (b) Branched multicellular  
(c) Unbranched multicellular (d) Unbranched unicellular
38. Sex organs are embedded in the thallus in [BHU 1996]  
(a) Moss (b) *Riccia*  
(c) *Azolla* (d) Fern
39. Sporophyte of *Riccia* contains [RPMT 1998]  
(a) Spores, elaters and nutritive cells  
(b) Spores and nutritive cells  
(c) Elaters and spores  
(d) Spores only
40. *Riccia* gametophyte develops from spore and ends in  
[RPMT 1996; BHU 2001]  
(a) Thallus (b) Capsule  
(c) Zygote (d) Spore
41. The development of *Funaria* gametophyte always initiated from [MP PMT 2003]  
(a) Antheridium (b) Protonema  
(c) Archegonia (d) Capsule
42. Plant body of *Riccia* is  
(a) Sporophyte (b) Gametophyte  
(c) Aquatic (d) Sporophyte
43. Thallus of *Riccia* is [CPMT 2003]  
(a) Triploid (b) Diploid  
(c) Haploid (d) Tetraploid
44. Meiosis (reduction division) in *Funaria* occurs in [AFMC 2001]  
(a) Egg (b) Zygote  
(c) Antherozoids (d) Spore mother cells
45. In moss capsule, the number of peristome whorls are [CPMT 1999; BHU 1999]  
(a) 1 (b) 2  
(c) 3 (d) 4
46. In *Funaria* (moss) spore germinates to produce [MP PMT 1999; Pb. PMT 2004; Odisha JEE 2011]  
(a) Protonema (b) Prothallus  
(c) Proembryo (d) Embryo
2. Who among the following was a paleobotanist [MDAT Bihar 1995; AIIMS 2004]  
(a) P. Maheshwari (b) S.R. Kashyap  
(c) Sahani (d) V. Puri
3. Which one of the following is a vascular cryptogam [CBSE PMT 2009]  
(a) *Equisetum* (b) *Ginkgo*  
(c) *Marchantia* (d) *Cedrus*
4. Which one of the following is heterosporous [CBSE PMT 2008; Kerala PMT 2010]  
(a) *Adiantum* (b) *Equisetum*  
(c) *Dryopteris* (d) *Salvinia*
5. In the prothallus of a vascular cryptogam, the antherozoids and eggs mature at different times. As a result [CBSE PMT 2007]  
(a) There is no change in success rate of fertilization  
(b) There is high degree of sterility  
(c) One can conclude that the plant is apomictic  
(d) Self fertilization is prevented
6. *Nephrolepis* is a [MHCET 2004]  
(a) Bryophyte (b) Pteridophyte  
(c) Gymnosperm (d) Angiosperm
7. Heterothallism refers to  
(a) Fusion is not accompanied with zygote formation  
(b) Fusion between morphologically similar strain  
(c) Fusion between the strains of structurally similar and physiologically different  
(d) All the above
8. Club moss belongs to [BHU 2006]  
(a) Algae (b) Pteridophyta  
(c) Fungi (d) Bryophyta
9. Prothallus is [KCET 1999; AIIMS 1999; Bihar CECE 2006]  
(a) Gametophyte, monoecious, Autotrophs present in pteridophyte  
(b) Gametophyte, monoecious, Autotrophs present in bryophytes  
(c) Gametophyte, dioecious, Autotrophs present in pteridophyte  
(d) Sporophyte, dioecious, heterotroph present in bryophyte
10. Common characteristic between bryophytes and pteridophytes is [MHCET 2004]  
(a) Vascularisation (b) Terrestrial habit  
(c) Water for fertilization (d) Independent sporophyte
11. During fertilization in ferns, male gamete reaches the female gamete through the agency of [HP PMT 2005]  
(a) Water (b) Insects  
(c) Chemicals (d) Winds
12. "Botanical snakes" are  
(a) Algae (b) Fungi  
(c) Bryophytes (d) Pteridophytes
13. Heterosporous pteridophytes always produce  
(a) Monoecious gametophytes  
(b) Dioecious gametophytes  
(c) Homothallic gametophytes  
(d) None of the above

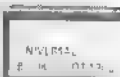
### Pteridophytes (General)

1. Which one of the following belongs to vascular cryptogams [RPMT 1997; BVP 2000; AMU (Med.) 2005; Odisha JEE 2011]  
(a) Bryophyta (b) Pteridophyta  
(c) Gymnosperms (d) Angiosperms

14. Pteridophytes are called vascular cryptogams, because they are non-seeded plants containing [KCET 2012]  
(a) Xylem and phloem (b) Only xylem  
(c) Only phloem (d) Neither xylem nor phloem
15. Most primitive members in which roots not present is [BHU 2005]  
**Or**  
Which of the following is a fossil pteridophyte  
(a) *Psilotum* (b) *Rhynia*  
(c) *Lycopodium* (d) *Selaginella*
16. Which pteridophyte is called as horse-tail [NCERT; Odisha JEE 2005]  
(a) *Equisetum* (b) *Lycopodium*  
(c) *Marsilea* (d) *Selaginella*
17. First vascular plant is [Odisha JEE 2005]  
(a) Thallophyta (b) Bryophyta  
(c) Pteridophyta (d) Spermatophyta
18. A collection of sporangia attached to placenta and covered over by indusium is known as  
(a) Sporophyll (b) Sorus  
(c) Cone (d) Ramenta
19. In pteridophytes, phloem is without [Odisha JEE 2005]  
(a) Sieve cells (b) Sieve tubes  
(c) Companion cells (d) Both (b) and (c)
20. Mosses and ferns are found in moist and shady places because both [AIIMS 2004; RPMT 2005]  
(a) Require presence of water for fertilization  
(b) Do not need sunlight for photosynthesis  
(c) Depend for their nutrition on micro-organisms which can survive only at low temperature  
(d) Can not compete with sun-loving plants
21. Which of the following Pteridophytes belong to class Pteropsida [Kerala PMT 2011]  
(a) *Equisetum* and *Psilotum*  
(b) *Lycopodium* and *Adiantum*  
(c) *Selaginella* and *Pteris*  
(d) *Pteris* and *Adiantum*  
(e) *Dryopteris* and *Psilotum*
22. A plant having vascular supply, producing spores but lacking seed is a [BHU 1995, 99; Manipal MEE 1995; CBSE PMT 1999; Odisha JEE 2004; MP PMT 2005]  
(a) Byophyte (b) Pteridophyte  
(c) Gymnosperm (d) Angiosperm
23. Formation of gametophyte directly from spore mother cell without meiosis is called [CPMT 1995]  
(a) Apospory (b) Apogamy  
(c) Apomictic (d) Apomixis
24. Seed habit originated firstly in some [CBSE PMT 1996]  
(a) Pteridophytes (b) Pines  
(c) Monocots (d) Dicots
25. Which of the following is not a pteridophyte [RPMT 1997]  
(a) *Ginkgo* (b) *Selaginella*  
(c) *Polypodium* (d) *Azolla*
26. Which of the following helps in coal formation [NCERT; AFMC 2000]  
(a) Bacteria (b) Gymnosperm  
(c) Pteridophytes (d) Archaeobacteria
27. Apogamous cells are  
(a) Haploid (b) Diploid  
(c) Polyploid (d) Triploid
28. Ectophloic siphonostele is found in [CBSE PMT 2005]  
(a) *Adiantum* and *Cucurbitaceae*  
(b) *Osmunda* and *Equisetum*  
(c) *Marsilea* and *Botrychium*  
(d) *Dicksoni* and *Maidenhair fern*

### Pteridium, Pteris, Dryopteris

1. Monoecious condition is found in  
(a) *Cycas* (b) *Selaginella*  
(c) *Pinus* (d) *Pteridium*
2. Distinct alternation of generation is found in [BHU 1999]  
(a) *Rhizopus* (b) Bacteria  
(c) Viruses (d) *Pteris* (Fern)
3. Multiflagellate male gametes (sperms) are found in  
(a) *Chlamydomonas* (b) *Funaria*  
(c) *Dryopteris* (d) *Riccia*
4. Eusporangiate fern is produced from [Odisha JEE 2009]  
(a) A group of sporangial, initial cell  
(b) Single initial cell  
(c) Epidermal cells  
(d) Hypodermal cells
5. Fern gametophyte is [Odisha JEE 2010]  
(a) Homothallic (b) Monoecious  
(c) Heterothallic (d) Both (a) and (b)
6. *Pteridium* possess [RPMT 2002]  
(a) Polycyclic dictyostele (b) Actinostele  
(c) Siphonostele (d) Amphiphloic siphonostele
7. Placenta in *Dryopteris* is the place of attachment of  
(a) Ovules (b) Ramenta  
(c) Sporangia (d) Archegonia
8. In *Dryopteris*, the sori are borne  
(a) Laterally (b) Abaxially  
(c) Adaxially (d) Marginally
9. In Pteridophytes/ *Dryopteris* meiosis occurs at the time of [JIPMER 1997; AIIMS 1998; CBSE PMT 2000; Wardha 2001]  
(a) Gamete formation (b) Spore formation  
(c) Formation of prothallus (d) Formation of sex organs



10. Fern prothallus is developed from [BVP 2002; MP PMT 2003]  
 (a) Elaters (b) Spore mother cells  
 (c) Spore (d) Zygote
11. Which one controls dehiscence of sporangium in *Dryopteris* [CBSE PMT 1995]  
 (a) Annulus (b) Tapetum  
 (c) Sorus (d) Indusium
12. Presence of ciliated antherozoids in *Dryopteris* indicates [CPMT 1995]  
 (a) Terrestrial habit (b) Aquatic ancestry  
 (c) Both (a) and (b) (d) None of these
13. Neck canal cells in *Dryopteris* are [CPMT 1994; CBSE PMT 2001; Odisha JEE 2002]  
 (a) One with two nuclei (b) Two  
 (c) One with one nucleus (d) Four
14. Brown hair found at the base of *Pteris* leaves are [APMEE 2002]  
 (a) Modified stipules (b) Modified leaflets  
 (c) Ramenta (d) Spines
15. Kidney-shaped covering of *Dryopteris* is  
 (a) Ramentum (b) Placenta  
 (c) Indusium (d) Sporophyll
16. Fern spores are usually [MP PMT 2009]  
 (a) Haploid (b) Diploid  
 (c) Triploid (d) Tetraploid
17. A fern differs from a moss in having [MP PMT 2009]  
 (a) Swimming archegonia  
 (b) Swimming antherozoids  
 (c) Independent gametophytes  
 (d) Independent sporophytes
18. Prothallus of the fern produces [MP PMT 2009]  
 (a) Spores  
 (b) Gametes  
 (c) Both spores and gametes  
 (d) Cones
19. A fern prothallus is bisexual. If fertilization takes place between their gametes then it is known as [BHU 2005]  
 (a) Cross fertilization (b) Self fertilization  
 (c) Isogamous (d) Viviparous
20. Dispersal of spores in fern takes place through [AFMC 2005]  
 (a) Annulus (b) Stomium  
 (c) Both (a) and (b) (d) Indusium
21. Fern plant is a [MP PMT 1995]  
 (a) Haploid gametophyte (b) Diploid gametophyte  
 (c) Diploid sporophyte (d) Haploid sporophyte
22. The aquatic fern which is an excellent biofertilizer is [CBSE PMT 1999, 2001]  
 (a) *Azolla* (b) *Salvinia*  
 (c) *Marsilea* (d) *Pteridium*
23. The gametophyte of fern bears [MHCET 2004; Pb. PMT 2004]  
 (a) True roots (b) Antheridia  
 (c) Archegonia (d) Both (b) and (c)
24. The circinate venation is the characteristic feature of ferns. It refers to [CPMT 2004; Manipal 2005; RPMT 2005]  
 (a) Coiling of young leaves  
 (b) Arrangement of leaves on stem  
 (c) Attachment of sori on leaves  
 (d) Heterophilly
25. Fern prothallus is  
 (a) Homothallic (b) Heterothallic  
 (c) Heterotrophic (d) Heteromorphic
26. Sporangia and spore bearing leaf in fern is called as [CPMT 1993; AFMC 1996; CBSE PMT 2001; DPMT 2006]  
 Or  
 New leaf of ferns is called [RPMT 1995]  
 (a) Ramentum (b) Sorus  
 (c) Indusium (d) Sporophyll/Frond
27. Heart shaped prothallus of fern bears [BVP 2001]  
 (a) Male sex organs (b) Female sex organs  
 (c) Bisexual (d) None of these
28. Young sporophyte of *Pteris* fern draws nourishment from prothallus through [CPMT 2009]  
 (a) Root (b) Rhizoids  
 (c) Foot (d) Haustoria
29. The first plants to appear after a forest fire are the ferns, this is because of the survival of their [Kerala PMT 2004]  
 (a) Spores (b) Leaves  
 (c) Fronds (d) Rhizomes  
 (e) Both (c) and (d)
30. Jacket of fern antheridium is composed of [DPMT 2004]  
 (a) 2 cells (b) 3 cells  
 (c) 4 cells (d) 5 cells
31. The number of spores in the sporangium of fern is [AFMC 1996; MHCET 2004]  
 (a) 16 (b) 32  
 (c) 64 (d) 128
32. In *Dryopteris* [JK CME 2002]  
 (a) Sporophyte is parasitic over gametophyte  
 (b) Sporophyte is independent  
 (c) Gametophyte is independent  
 (d) Both (b) and (c)
33. What is correct [Odisha JEE 2002]  
 (a) Protonema of moss and prothallus of *Dryopteris* are sporophytic  
 (b) Protonema of moss and prothallus of *Dryopteris* are gametophytic  
 (c) Moss protonema is sporophytic, *Pteris* prothallus is gametophytic but plant body of *Pteris* and *Funaria* are gametophytic  
 (d) Plant body of moss is gametophytic while that of *Dryopteris* is both gametophytic and sporophytic
34. In *Dryopteris* the opening mechanism of sporangium is effectively operated by [MHCET 2003]  
 (a) Stalk (b) Stomium  
 (c) Annulus (d) None of these

35. In fern, young leaves are protected by  
(a) Rhizome (b) Indusium  
(c) Sorl (d) Ramenta
36. Which of the following is not involved in the fertilization of fern  
(a) Pollen tube (b) Water  
(c) Archegonia (d) Flagellated sperms
37. Fern stele is [CPMT 1994; Odisha JEE 2012]  
(a) Dictyostele (b) Siphonostele  
(c) Protostele (d) None of these
38. Spore of fern represents  
(a) Sporophytic stage  
(b) Gametophytic stage  
(c) Sporophytic and gametophytic stage  
(d) Apomictic stage
39. The sperm of fern is [AFMC 1995]  
(a) Biciliate and coiled  
(b) Multiciliate and sickle-shaped  
(c) Multiflagellate and coiled  
(d) Biciliate and sickle-shaped
40. Sometime prothallus of fern give rise to a fern plant. It is an example of [AIIMS 2013]  
(a) Apospory (b) Parthenogenesis  
(c) Parthenocarp (d) Apogamy
41. Antherozoids of fern are [Bihar MDAT 1992]  
(a) Spherical (b) Coiled  
(c) Multiflagellate (d) All of the above
42. In fern, spores are formed in  
(a) Sporangium (b) Oogonium  
(c) Archegonium (d) Stomium
43. The cells of fern prothallus contains nucleus with  
(a)  $4n$  chromosomes (b)  $3n$  chromosomes  
(c)  $2n$  chromosomes (d)  $n$  chromosomes
44. In fern plant, the ejection of spores with force is achieved by the  
(a) Sporangiphore (b) Annulus  
(c) Stomium (d) Indusium
45. In fern, sporangia are borne on the  
(a) Margin of leaf (b) Abaxial side of leaf  
(c) Adaxial side of leaf (d) Only on the tip of leaf
46. The shape of sporangium in fern is  
(a) Biconvex (b) Circular  
(c) Biconcave (d) Plano-convex
3. In *Selaginella trabeculae* are the modification of [MP PMT 2000, 09]  
(a) Epidermal cells (b) Cortical cells  
(c) Endodermal cells (d) Pericycle cells
4. Polystelic stem is seen in  
(a) *Cycas* (b) *Riccia*  
(c) *Selaginella* (d) *Funaria*
5. Which of the following does not belong to *Selaginella*  
(a) Ramenta (b) Trabeculae  
(c) Rhizophore (d) Ligule
6. In *Selaginella* male gametes are [MP PMT 2000]  
(a) Aflagellated (b) Monoflagellated  
(c) Biflagellated (d) Multiflagellated
7. Megasporangium of *Selaginella* is equivalent to which structure of *Pinus*  
(a) Ovule (b) Nucellus  
(c) Female gametophyte (d) Seed
8. Antherozoids of *Selaginella* has [CBSE PMT 1990]  
(a) Elongated body with many flagella  
(b) An elongated body with two flagella at one end  
(c) Top shaped body with many flagella  
(d) Oval body with two flagella at one end
9. *Selaginella* differs from *Pteris* (fern) in which of the following character [CMC Vellore 1993]  
(a) Absence of seed  
(b) Absence of vessels in xylem  
(c) Need water for fertilization  
(d) Heterosporous condition
10. Rhizophore in *Selaginella* is [Pune CET 1998]  
(a) A modified leaf (b) A root  
(c) A shoot (d) Organ sui genesis
11. Trabeculae endodermis is found in [MP PMT 2000]  
(a) Axis and capsule of moss plant  
(b) Stem of *Selaginella*  
(c) Stem of *Cycas*  
(d) Stem of *Pinus*
12. Which of the following is not correct with reference to *Selaginella*  
(a) *Selaginella* is commonly distributed on hills and plains  
(b) Some species of *Selaginella* are truly xerophytic  
(c) The vascular cylinder is protostelic  
(d) The endodermis is trabeculated
13. Heteromorphic alternation of generations is found in [MP PMT 1998]  
(a) *Spirogyra* (b) *Mucor*  
(c) *Selaginella* (d) *Pinus*
14. In which one of the following species of *Selaginella*, the apex continues its vegetative growth beyond the formation of strobilus  
(a) *S. helvetica* (b) *S. cuspidata*  
(c) *S. rupestris* (d) None of these
15. Which of the following is not common in *Funaria* and *Selaginella* [CBSE PMT 1994]  
(a) Roots (b) Archegonium  
(c) Embryo (d) Motile sperms
16. The number of male prothallial cells in *Selaginella* are [MP PMT 1993]  
(a) One (b) Two  
(c) Four (d) Nil

### Selaginella

1. Which one of the following is considered important in the development of seed habit [Pune CET 1998; CBSE PMT 2009; Odisha JEE 2011]  
Or  
*Selaginella* has the character of evolutionary importance. That character is [JIPMER 1993; BHU 1994; MP PMT 2012]  
(a) Dependent sporophyte (b) Heterospory  
(c) Haplontic life cycle (d) Free-living gametophyte
2. Number of megaspore in *Selaginella rupestris* is [AFMC 1995]  
(a) One (b) Two  
(c) Six (d) Seven



17. The stem of *Selaginella* is anatomically characterised by the presence of [MP PMT 1994]  
 (a) Siphonostele (b) Amphiphloic siphonostele  
 (c) Protostele (d) Ectophloic siphonostele
18. Adaxial outgrowth from the base of leaves in *Selaginella* is called [MHCET 2001; BHU 2005]  
 (a) Stipule (b) Ligule  
 (c) Trabaculæ (d) Velum
19. Physiological heterospory is seen in [DPMT 2004]  
 (a) *Chlamydomonas* (b) *Rhizopus*  
 (c) *Selaginella* (d) *Hycopodium*
20. Spores with chloroplast is present in [DPMT 2004]  
 (a) *Selaginella* (b) *Equisetum*  
 (c) *Puccinia* (d) *Rhizopus*
21. *Selaginella* and *Salvinia* are considered to represent a significant step toward evolution of seed habit because [CBSE PMT (Malna) 2011]  
 (a) Megaspores possess endosperm and embryo surrounded by seed coat  
 (b) Embryo develops in female gametophyte which is retained on parent sporophyte  
 (c) Female gametophyte is free and gets dispersed like seeds  
 (d) Female gametophyte lacks archegonia
22. The main plant body of *Selaginella* sp. is [MP PMT 1997]  
 (a) Gametophyte  
 (b) Sporophyte  
 (c) Both gametophyte and sporophyte  
 (d) Halophyte
23. Which of the following is known as 'resurrection plant' [CPMT 1999; HPMT 2005]  
 (a) *Selaginella* (b) *Welwitschia*  
 (c) *Rafflesia* (d) *Chlorella*
24. In *Selaginella*, reduction division occurs during the formation of [CBSE PMT 1994; AIIMS 1998]  
 (a) Sperms (b) Microspores only  
 (c) Megaspores only (d) Both (b) and (c)
5. During adverse season, therophytes survive by [CBSE PMT 1997]  
 (a) Bulbs (b) Corms  
 (c) Rhizomes (d) Seeds
6. In which of the following groups would you place a plant which produces seeds but lacks flower and fruits [CPMT 1996; AMU (Med.) 2005]  
 (a) Fungi (b) Bryophytes  
 (c) Pteridophytes (d) Gymnosperms
7. Most of the gymnosperms have  
 (a) Only antheridia  
 (b) Both antheridia and archegonia  
 (c) Archegonia but no antheridia  
 (d) Both absent
8. Gymnosperms do not have  
 (a) Trees (b) Shrubs  
 (c) Lianas (d) Herbs
9. In gymnosperms pollination is exclusively by [NCERT; CBSE PMT 1993; RPMT 1999]  
 (a) Animals (b) Wind  
 (c) Water (d) Insects
10. Fruits are not found in gymnosperms plants because [AFMC 1995; Odisha JEE 2010]  
 (a) They are seedless plants  
 (b) They are not pollinated  
 (c) They have no ovary  
 (d) Process of fertilization does not take place in them
11. Mark the gymnospermous plant in which archegonium is absent [MP PMT 2012]  
 (a) *Pinus* (b) *Ephedra*  
 (c) *Cycas* (d) *Gnetum*
12. The young meristematic cells of leaves and stem of a gymnosperm has 16 chromosomes, the number of chromosomes in the endosperm of the same gymnosperm shall be [MP PMT 2013]  
 (a) 16 (b) 32  
 (c) 24 (d) 8
13. In gymnosperms, the pollen chamber represents [CBSE PMT 2007]  
 (a) A cell in the pollen grain in which the sperms are formed  
 (b) A cavity in the ovule in which pollen grains are stored after pollination  
 (c) An opening in the megagametophyte through which the pollen tube approaches the egg  
 (d) The microsporangium in which pollen grains develop

### Gymnosperm (General)

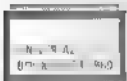
1. Which gymnospermic order includes all fossil plants [Odisha JEE 2009]  
 (a) Cycadofilicales (b) Coniferales  
 (c) Gnetales (d) Cycadales
2. Which one of the following classes is included under gymnosperms [Kerala PMT 2009]  
 (a) Lycopsida (b) Bryopsida  
 (c) Cycadopsida (d) Pteropsida  
 (e) Sphenopsida
3. Naked seeds of gymnosperms meant for absence of which of the following [BHU 2008]  
 (a) Seed coat (b) Integument  
 (c) Embryo (d) None of these
4. In gymnosperms, the ovule is naked because [CPMT 2004; MP PMT 2009]  
 (a) Ovary wall is absent (b) Integuments are absent  
 (c) Perianth is absent (d) Nucellus is absent
14. Consider the following statements regarding gymnosperms and choose the correct option  
 (A) In gymnosperms, the male and female gametophytes have an independent existence  
 (B) The multicellular female gametophyte is retained with in the megasporangium  
 (C) The gymnosperms are heterosporous of these statements [Kerala PMT 2010]  
 (a) (A) and (B) are true but (C) is false  
 (b) (A) and (C) are true but (B) is false  
 (c) (B) and (C) are false but (A) is true  
 (d) (A) and (C) are false but (B) is true  
 (e) (B) and (C) are true but (A) is false

15. Canada balsam is an oleoresin obtained from [NCERT]  
 (a) *Abies balsamea* (b) *Impatiens balsamia*  
 (c) *Pinus* sp. (d) *Helianthus annuus*
16. The lateral conduction in gymnospermic leaf is by [MHCET 2002]  
 (a) Veins (b) Xylem parenchyma  
 (c) Transfusion tissue (d) Medullary rays
17. Which of the following gymnosperm is a bushy trailing shrub [Kerala PMT 2007]  
 (a) *Ephedra* (b) *Cycas*  
 (c) *Pinus* (d) *Araucaria*  
 (e) *Cedrus*
18. Gymnosperms are also called soft wood spermatophytes because they lack [NCERT; CBSE PMT (Pre.) 2012]  
 (a) Cambium (b) Phloem fibres  
 (c) Thick-walled tracheids (d) Xylem fibres
19. In which class of gymnosperms, fossils are present [CPMT 1995]  
 (a) Cycadophyta (b) Coniferophyta  
 (c) Gnetopsida (d) Both (a) and (b)
20. What is the similarity between gymnosperms and angiosperms [CPMT 1996]  
 (a) Phloem of both have companion cells  
 (b) Endosperm is formed before fertilization in both  
 (c) Origin of ovule and seed is similar in both  
 (d) Both have leaves, stem and roots
21. Which of the following is living fossil [CBSE PMT 1996, 97; Odisha JEE 2005, 08]  
 (a) *Pinus* (b) *Ginkgo biloba*  
 (c) *Thuja* (d) *Deodar*
22. Vessels are found in [DPMT 2004]  
 (a) *Ephedra* (b) *Selaginella*  
 (c) *Funaria* (d) All gymnosperms
23. Resin duct of a gymnospermous stem is an example of [BHU 1999; Pb. PMT 2004]  
 (a) Big vacuole (b) Lysigenous cavity  
 (c) Inter cellular space (d) Schizogenous cavity
24. The arrangement of megaspores in a tetrad in a gymnosperm is [CPMT 2000]  
 (a) Decussate (b) Tetrahedral  
 (c) Linear (d) Isobilateral
25. Which of the following is a character of gymnospermous wood [MP PMT 2010, 12]  
 (a) Porous (b) Ring porous  
 (c) Diffused porous (d) Non-porous
26. Which of the following is not the feature of gymnosperms [BHU 2005; CPMT 2009]  
 (a) Parallel venation  
 (b) Perennial plants  
 (c) Distinct branches (long and short branches)  
 (d) Xylem with vessels
27. In gymnosperms how many male gametes are produced by each pollen grain [HP PMT 2005]  
 (a) 4 (b) 3  
 (c) 2 (d) 1
28. A typical gymnospermous plant has 8 chromosomes in leaf cells. What will be number of chromosomes in the cells of its gametophyte [HP PMT 2005]  
 (a) 16 (b) 8  
 (c) 4 (d) 24
29. Conifers differ from grasses in the [CBSE PMT 2006]  
 (a) Absence of pollen tubes  
 (b) Formation of endosperm before fertilization  
 (c) Production of seeds from ovules  
 (d) Lack of xylem tracheids

### Pinus

1. The phenomenon of sulphur shower in pine forest is due to [Odisha JEE 2008]  
 (a) Presence of Sulphur  
 (b) Presence of insects  
 (c) Release of pollen grains in prodigious amount  
 (d) Large number of fruits
2. Which one of the following plants is monoecious [NCERT; RPMT 1997, 99; MP PMT 1997, 99; CBSE PMT 2009; CBSE PMT (Mains) 2010]  
 (a) *Marchantia* (b) *Pinus*  
 (c) *Cycas* (d) *Papaya*
3. Annual rings are well seen in [Pune CET 1998]  
 (a) *Selaginella* stem (b) *Cycas* wood  
 (c) *Pinus* wood (d) All the above
4. Pollination of pollen grains in *Pinus* takes place at  
 (a) One celled stage (b) Two celled stage  
 (c) Three celled stage (d) Four celled stage
5. Non-motile male gametes are formed in [MP PMT 2000]  
 (a) *Funaria* (b) *Selaginella*  
 (c) Fern (d) *Pinus*
6. Which one of the following is matched incorrectly [AMU (Med.) 2010]  
 (a) *Pinus* : coralloid roots (b) *Sequoia* : tap roots  
 (c) *Cycas* : unbranched stem (d) *Cedrus* : branched stem
7. Popular dry fruit "chilgoza" is produced by [NCERT; CPMT 1995; MP PMT 2011]  
 (a) *Pinus sylvestris* (b) *Pinus monophylla*  
 (c) *Pinus gerardiana* (d) *Pinus roxburghii*
8. *Pinus* belongs to the class [KCET 2011]  
 (a) Gnetopsida (b) Cycadopsida  
 (c) Coniferopsida (d) Sphenopsida
9. Consider the following four statements whether they are correct or wrong  
 (A) The sporophyte in liverworts is more elaborate than that in mosses  
 (B) *Salvinia* is heterosporous  
 (C) The life-cycle in all seed-bearing plants is diplontic  
 (D) In *Pinus* male and female cones are borne on different trees
- The two wrong statements together are [CBSE PMT (Mains) 2011]  
 (a) Statements (B) and (C) (b) Statements (A) and (B)  
 (c) Statements (A) and (D) (d) Statements (A) and (D)
10. The male cone of *Pinus* is modified  
 (a) Long shoot (b) Needle leaves  
 (c) Dwarf shoot (d) None of the above
11. Which of the following structures in *Pinus* are haploid [JIPMER 1993; MP PMT 2002]  
 (a) Megaspore, integument, root  
 (b) Endosperm, megaspore, pollen grain  
 (c) Pollen grain, leaf, root  
 (d) Megaspore, endosperm, embryo

12. Pine wood consists of almost entirely
  - (a) Tracheids
  - (b) Vessels
  - (c) Equal number of tracheids and vessels
  - (d) More vessels and less tracheids
13. Winged seeds are found in [CMC Vellore 1993; CPMT 1995; BVP 2002; MP PMT 2004, 12]
  - (a) *Cycas*
  - (b) *Pinus*
  - (c) *Papaver* species
  - (d) None of the above
14. In *Pinus* seeds there are
  - (a) Two cotyledons
  - (b) One cotyledon
  - (c) Fleshy cotyledons
  - (d) Many cotyledons
15. Male prothallus (gametophyte) in *Pinus* is having
  - (a) 1 prothallial cell
  - (b) 2 prothallial cells
  - (c) 4 prothallial cells
  - (d) A mass of cells
16. Which of the following tissue is present in the leaves of *Pinus* and serve to conduct water and food [CBSE PMT 1998; CPMT 1999, 2001; AFMC 2002; Manipal 2005]
  - (a) Xylem
  - (b) Phloem
  - (c) Transfusion tissue
  - (d) Conducting tissue
17. In the embryo of *Pinus* rosette cells lie
  - (a) Above suspensor cells
  - (b) Between suspensor and embryonal cells
  - (c) Between primary and secondary suspensor cells
  - (d) Between embryonal and apical cells
18. Resin and turpentine are obtained from [NCERT]
  - (a) *Cycas*
  - (b) *Pinus*
  - (c) *Abies*
  - (d) *Cedrus*
19. The winged pollen grain of *Pinus* sp. are produced in [MP PMT 1997, 2004; BVP 2002]
  - (a) Pollen chamber
  - (b) Anther
  - (c) Tapetum
  - (d) Microsporangium
20. Of the following, the false character with respect to *Pinus* is
  - (a) Bract and ovuliferous scales
  - (b) Embryo with two cotyledons
  - (c) Resin canals in needles
  - (d) Tracheids with bordered pits
21. Cataphylls are
  - (a) Leaves of *Selaginella*
  - (b) Scaly leaves of *Pinus*
  - (c) Needles of *Pinus*
  - (d) Foliar leaves of *Pinus*
22. Male gametophyte (mature pollen grain) of *Pinus* is found to be
  - (a) 10 celled
  - (b) 6 celled
  - (c) 4 celled
  - (d) 2 celled
23. The wood of *pinus* is [MP PMT 2000, 12; AMU (Med.) 2006]
  - (a) Pycnoxylic and monoxylous
  - (b) Pycnoxylic and heteroxylous
  - (c) Manoxylous and homoxylous
  - (d) Manoxylous and heteroxylous
24. Which statement is correct with reference to *Pinus*
  - (a) It is of much economic value
  - (b) It is cosmopolitan in distribution
  - (c) It grows in deserts and exhibits xerophytic character
  - (d) It forms deciduous trees in temperate region
25. *Pinus* produces [CMC Vellore 1994; CPMT 1995]
  - (a) No seeds
  - (b) Flowers
  - (c) No vascular tissues
  - (d) Naked seeds in cones
26. In *Pinus*, the spur (dwarf shoot) has [MP PMT 1993]
  - (a) One needle
  - (b) Two needles
  - (c) Three needles
  - (d) All correct
27. The secondary wood of *Pinus* is characterised by [MP PMT 1993]
  - (a) Presence of resin cells
  - (b) Presence of resin ducts
  - (c) Absence of resin ducts
  - (d) Presence of vessels
28. Which one of the following alternatives represents the gametophytic phase in *Pinus* [MP PMT 1994]
  - (a) *Pinus* plant
  - (b) Zygote
  - (c) Micro and megaspores
  - (d) Male and female cones
29. Endosperm of *Pinus* is
  - (a) Male gametophyte
  - (b) Female gametophyte
  - (c) Sporophyte
  - (d) None of the above
30. The gametophyte is not an independent, free-living generation in [CBSE PMT (Pre.) 2011; AIPMT (Cancelled) 2015]
  - (a) *Pinus*
  - (b) *Polytrichum*
  - (c) *Adiantum*
  - (d) *Marchantia*
31. The wing in *Pinus* seed originates from [MP PMT 1993]
  - (a) Integument
  - (b) Adaxial surface of ovuliferous scale
  - (c) Bract scale
  - (d) Cone axis
32. Seed of *Pinus* shows three generations as [J & K CET 2002]
  - (a) Parent sporophyte, gametophyte and future sporophyte
  - (b) Parent gametophyte, sporophyte and future gametophyte
  - (c) Parent sporophyte, sporophyte, future gametophyte
  - (d) None of these
33. In *Pinus* male gametes are produced in the pollen tube by the division of which of the following cells [BHU 2001]
  - (a) Body cell
  - (b) Stalk cell
  - (c) Tube cell
  - (d) Prothallial cell
34. The seed of *Pinus* sp. is [MP PMT 1997]
  - (a) Uneconomic and nonendospermic
  - (b) Abaxial and rounded
  - (c) Adaxial and endospermic
  - (d) Hypogeal and monocotyledonous
35. In *Pinus* male and female reproductive structures occur [MP PMT 1996]
  - (a) On different branches of the same plant
  - (b) On different plants
  - (c) On same branch
  - (d) None of these
36. The pollination in *Pinus* is [AFMC 1995]
  - (a) Entomophilous
  - (b) Anemophilous
  - (c) Hydrophilous
  - (d) Malscophilous
37. In *Pinus* only lower part of oospore is concerned with the development of embryo, such development is [CBSE PMT 1993]
  - (a) Meroblastic
  - (b) Periblastic
  - (c) Mesoblastic
  - (d) None of these



38. Female cone of *Pinus* is considered equivalent to  
[MP PMT 2009]

- (a) Dwarf shoot (b) Long shoot  
(c) Needles (d) Scale leaves

39. Siphonogamous fertilization takes place in  
(a) Bryophytes (b) *Selaginella*  
(c) Fern (d) *Pinus*

40. *Pinus* shows [CBSE PMT 2001; BHU 2006]  
(a) Simple polyembryony  
(b) Cleavage polyembryony  
(c) Both simple and cleavage polyembryony  
(d) None of the above

41. A microsporophyll in *Pinus* has [Pune CET 1998; Kerala PMT 2004]  
(a) One microsporangium on the adaxial side  
(b) One microsporangium on the abaxial side  
(c) Two microsporangia on the abaxial side  
(d) Two microsporangia on the adaxial side  
(e) Four microsporangia on the lower side

### Cycas

- Diploxylic or polyxylic vascular bundles are found in  
(a) *Pinus* (b) *Dryopteris*  
(c) *Cycas* (d) *Funaria*
- In which plant largest sperms (antherozoids) are found  
[CBSE PMT 1998; CPMT 1998; MHCET 2000; BHU 2012]  
(a) *Cycas* (b) *Pinus*  
(c) Mango (d) Sunflower
- Fern character in *Cycas* is [AFMC 2001]  
(a) Coralloid roots (b) Tap root system  
(c) Circinate venation (d) Reticulate venation
- Coralloid roots of *Cycas* are useful in [MHCET 2004; BHU 2005]  
(a)  $N_2$ -fixation (b) Absorption of water  
(c) Transpiration (d) Fixation
- Cycas circinalis* is a source of [BVP 2004; CPMT 2005]  
(a) Resin (b) Timber  
(c) Essential oil (d) Starch (Sago)
- The stem of female *Cycas* plant is a [MHCET 2002]  
(a) Monopodium (b) Sympodium  
(c) Rhizomatous (d) Dichotomous
- Sterile part of *Cycas* microsporophyll is [MHCET 2004]  
(a) Apophysis (b) Sporophore  
(c) Middle part (d) Lower part
- Polyembryony seen in *Cycas* is  
(a) Potential true polyembryony  
(b) Potential true polyembryony and cleavage polyembryony  
(c) Adventive polyembryony  
(d) All of these
- Cycas* leaflets are [MHCET 2004]  
(a) Sessile, straight, oval  
(b) Sessile, straight, linear-lanceolate  
(c) Sessile, straight, spiny  
(d) Sessile, smooth, twisted

- The secondary growth in stem of *Cycas* is brought about by  
(a) Persistent cambium  
(b) Short lived cambium  
(c) Number of cambia produced in succession  
(d) Isolated strips of cambium
- Which one of the following is a living fossil [CBSE PMT 2004]  
(a) *Saccharomyces* (b) *Spirogyra*  
(c) *Cycas* (d) Moss
- Top-shaped multiciliate male gametes, and the mature seed which bears only one embryo with two cotyledons, are characteristic features of [CBSE PMT 2005]  
(a) Polypetalous angiosperms  
(b) Gamopetalous angiosperms  
(c) Conifers  
(d) Cycads
- Negatively geotropic roots are found in [Odisha JEE 2005]  
(a) *Colocasia* (b) *Cycas*  
(c) *Cactus* (d) *Coleus*
- Spermatozoid of *Cycas* is [APMEE 1995; JIPMER 2000]  
(a) Biflagellate (b) Nonflagellate  
(c) Uniflagellate (d) Multiciliated
- Which is not a characteristic feature of *Cycas*  
(a) Naked ovules (b) Circinate vernation  
(c) Vessels (d) Girdling leaf traces
- Cycas* has the largest  
(a) Ovule (b) Egg  
(c) Sperm (d) All of these
- Cycas* is  
(a) Hermaphrodite (b) Dioecious  
(c) Monoecious (d) None of these
- Cycas revoluta* is [Pb. PMT 1997; Chd. CET 1999; CPMT 2002, 10; RPMT 2005]  
(a) Date Palm (b) Sea Palm  
(c) Royal Palm (d) Sago Palm
- Wood of *Cycas* is [APMEE 1996; Wardha 2002; DPMT 2004]  
(a) Monoxyle and manoxyle  
(b) Manoxyle and polyxylic  
(c) Diploxylic  
(d) Monoxyle
- Cycas* contains  
(a) Mucilage ducts (b) Laticiferous vessels  
(c) Resin ducts (d) Oil ducts
- In *Cycas*, pollination is by [DPMT 1999]  
(a) Wind (b) Insect  
(c) Water (d) Both (a) and (b)
- In *Cycas*, the ovules are attached to megasporophyll  
(a) Laterally (b) Dorsally  
(c) Ventrally (d) Apically
- Cycas* resembles angiosperms in having [MP PMT 1996]  
(a) Circinate vernation in leaves  
(b) Vessels  
(c) Motile sperms  
(d) Ovules

24. *Cycas* is living fossil as it has [BHU 1992]  
 (a) Ciliated sperms  
 (b) Structure like that of Tree Fern  
 (c) Restricted occurrence in certain areas  
 (d) Been found in fossil state also
25. In *Cycas*, the endosperm is  
 (a) Sporophytic structure (b) Gametophytic structure  
 (c) New structure (d) Formed after fertilization
26. Male gametes of cycads are [CPMT 1992]  
 (a) Rounded and nonciliate  
 (b) Sickle – shaped biflagellate  
 (c) Boat – shaped nonciliate  
 (d) Large, top-like, spirally twisted with cilia
27. Coralloid roots of *Cycas* possess a symbiotic alga [CPMT 1993; Bihar PMT 1996; BHU 1998; Pb. PMT 1999]  
 (a) *Aulosira* (b) *Spirogyra*  
 (c) *Ulothrix* (d) *Anabaena*
28. Select one of the following pairs of important features distinguishing *Gnetum* from *Cycas* and *Pinus* and showing affinities with angiosperms [CBSE PMT 2008]  
 (a) Perianth and two integuments  
 (b) Embryo development and apical meristem  
 (c) Absence of resin duct and leaf venation  
 (d) Presence of vessel elements and absence of archegonia
29. In *Cycas* Pollination takes place in [CPMT 1990, 93; BHU 2005, 12; Odisha JEE 2010]  
 (a) 3-celled stage (b) 4-celled stage  
 (c) 2-celled stage (d) 1-celled stage
30. Sago of *Cycas* is given to patients with stomach disorders because it is [AIIMS 1997]  
 (a) Cheap  
 (b) Easily digestible with less starch  
 (c) Tastier  
 (d) With high nutritive value
31. Which is incorrect about *Cycas* [CBSE PMT 1998]  
 (a) Its xylem has vessels  
 (b) It has circinate venation  
 (c) It does not have well organised female flower  
 (d) Its roots possess some blue-green algae
32. Vegetative reproduction in *Cycas* occurs by [RPMT 1998]  
 (a) Scale leaves (b) Sporophylls  
 (c) Bulbils (d) Fragmentation
33. Megasporophyll of *Cycas* is homologous to [AIIMS 2002]  
 (a) Carpel (b) Stamen  
 (c) Petal (d) Sepal
34. *Cycas* has two cotyledons but it is not included under angiosperms because it has [CBSE PMT 2001]  
 (a) Circinate ptyxis (b) Compound leaves  
 (c) Monocot like stem (d) Naked seeds
35. Diploxylic condition occurs in *Cycas* in [APMEE 2002]  
 (a) Root (b) Stem  
 (c) Coralloid root (d) Leaflet
36. Microsporangia of *Cycas* occur over microsporophyll [AIIMS 1996; RPMT 2000]  
 (a) Adaxially (b) Abaxially  
 (c) Laterally (d) Marginally
37. A characteristic of *Cycas* that resembles ferns is [AFMC 2001; Odisha JEE 2012]  
 (a) Circinate ptyxis  
 (b) Sori in microsporophyll  
 (c) Uniflagellated male gamete  
 (d) Both (a) and (b)
38. *Cycas* and *Adiantum* resemble each other in having [CBSE PMT (Pre.) 2012]  
 (a) Seeds (b) Motile Sperms  
 (c) Cambium (d) Vessels
39. Ptyxis in *Cycas* is  
 (a) Simple (b) Circular  
 (c) Circinate (d) None of these
40. Early embryogeny in *Cycas* is characterized by  
 (a) Absence of suspensor cell  
 (b) Presence of expanded free nuclear division  
 (c) Reduced free nuclear division  
 (d) Many cotyledons
41. Identify the pair that exhibit circinate vernation [KCET 2010]  
 (a) *Psilotum* and *Riccia*  
 (b) *Equisetum* and *Selaginella*  
 (c) *Nephrolepis* and *Cycas*  
 (d) *Riccia* and *Nephrolepis*
42. Which of the following taxa shows zooidogamous oogamy  
 (I) *Spirogyra* (II) *Funaria*  
 (III) *Pteris* (IV) *Cycas*  
 The correct answer is [EAMCET 2009]  
 (a) I, II, III (b) I, III, IV  
 (c) I, II, IV (d) II, III, IV
43. Algal zone is characteristic of [CPMT 1994]  
 (a) Normal root of *Cycas* (b) Root of *Pinus*  
 (c) Coralloid roots of *Cycas* (d) Stem of *Cycas*

### Angiosperm

1. Seed are found in [MP PMT 2005; AMU (Med.) 2006]  
 (a) Angiosperm (b) Bryophyta  
 (c) Pteridophyta (d) Algae
2. Which of the following contain xylem vessel [AFMC 1996; J & K CET 2002; Haryana PMT 2005; MP PMT 2005]  
 (a) Bryophyte (b) Pteridophyta  
 (c) Both (a) and (b) (d) Angiosperm
3. Vessels and Companion cells are characteristics of [BCECE 2005; MP PMT 2005, 07]  
 (a) Angiosperm (b) Gymnosperm  
 (c) Pteridophyta (d) Fern
4. The stele found in monocot is [DPMT 2004]  
 (a) Haplostele (b) Atactostele  
 (c) Dictyostele (d) Actinostele
5. Tap roots are commonly found in  
 (a) Gymnosperms (b) Angiosperms  
 (c) Dicots (d) Monocots
6. Which of the following is/are grouped under phanerogams [BHU 2004]  
 (a) Angiosperms (b) Gymnosperms  
 (c) Pteridophytes (d) Both (a) and (b)
7. Which is not a monocot [BHU 2005]  
 (a) Rose (b) Orchids  
 (c) Palms (d) Banana

8. Which of the following is a saprophytic angiosperm [MHCET 2001]  
 (a) *Cuscuta* (b) *Neottia*  
 (c) *Agaricus* (d) Mango
9. An angiosperm is different from a gymnosperm in the absence of  
 (a) Vascular tissue (b) Ovary  
 (c) Seed (d) Naked ovule
10. Which of the following is considered as more evolved  
 (a) Dicot plant (b) Monocot plant  
 (c) Data are incomplete (d) Both (a) and (b)
11. In which of the following secondary growth takes place [MP PMT 2001]  
 (a) *Riccia* (b) *Funaria*  
 (c) *Selaginella* (d) None of these
12. An angiosperm differs from a gymnosperm by possessing [MHCET 2002]  
 (a) Ovule (b) Xylem vessels  
 (c) Xylem tracheids (d) Seed
13. Largest flower *Rafflesia* is [RPMT 1995; CPMT 1998]  
 (a) Total stem parasite (b) Total root parasite  
 (c) Partial stem parasite (d) Partial root parasite
14. Which of the following is the tallest tree of the world [HP PMT 2005; AMU (Med.) 2006]  
 (a) *Eucalyptus regnans* (b) *Sequoia sempervirens*  
 (c) *Pinus logifolia* (d) *Pinus roxburgii*
15. Male gametophyte with least number of cells is present in [CBSE PMT 2014]  
 (a) *Lilium* (b) *Pinus*  
 (c) *Pteris* (d) *Funaria*
16. In majority of angiosperms [NEET (Phase-II) 2016]  
 (a) A small central cell is present in the embryo sac  
 (b) Egg has a filiform apparatus  
 (c) There are numerous antipodal cells  
 (d) Reduction division occurs in the megaspore mother cells
5. Plants of this group are diploid and well adapted to extreme conditions. They grow bearing sporophylls in compact structures called cones. The group in reference is [NCERT]  
 (a) Monocots (b) Dicots  
 (c) Pteridophytes (d) Gymnosperms
6. If the diploid number of a flowering plant is 36. What would be the chromosome number in its endosperm [NCERT]  
 (a) 36 (b) 18  
 (c) 54 (d) 72
7. Protonema is [NCERT]  
 (a) Haploid and is found in mosses  
 (b) Diploid and is found in liverworts  
 (c) Diploid and is found in pteridophytes  
 (d) Haploid and is found in pteridophytes
8. The giant Redwood tree (*Sequoia sempervirens*) is a/an [NCERT]  
 (a) Angiosperm (b) Free fern  
 (c) Pteridophyte (d) Gymnosperm

## Critical Thinking

### Objective Questions

1. Which one of the following is commonly called a "Maidenhair fern" [Kerala PMT 2006]  
 (a) *Pteridium* (b) *Adiantum*  
 (c) *Dryopteris* (d) *Pteris*
2. *Pinus* seed is originated in [MP PMT 2003]  
 (a) Capsule (b) Microsporophyll  
 (c) Microsporangia (d) Megasporophyll
3. In which one of the following male and female gametophytes do not have free living independent existence [CBSE PMT 2008]  
 (a) *Polytrichum* (b) *Cedrus*  
 (c) *Pteris* (d) *Funaria*
4. Consider the following statements with respect to gymnosperms and angiosperms  
 A. Double fertilization is an event unique to gymnosperms  
 B. Angiosperms range in size from microscopic, *Wolffia* to tall trees of *Sequoia*  
 C. In gymnosperms the seeds are not covered  
 D. In gymnosperms the male and female gametophytes have an independent free living existence  
 Of the above statements [Kerala PMT 2012]  
 (a) A and B alone are correct  
 (b) C alone is correct  
 (c) B and C alone are correct  
 (d) C and D alone are correct  
 (e) D alone is correct
5. Two type of cells hyaline and green or with various shades are characteristic of bryophytes in  
 (a) *Funaria hygrometrica*  
 (b) *Polytrichum commune*  
 (c) *Sphagnum papillosum*  
 (d) *Porella platyphylla*

## NCERT

### Exemplar Questions

1. Fusion of two gametes which are dissimilar in size is termed as [NCERT]  
 (a) Oogamy (b) Isogamy  
 (c) Anisogamy (d) Zoogamy
2. Holdfast, stipe and frond constitutes the plant body in case of [NCERT]  
 (a) Rhodophyceae (b) Chlorophyceae  
 (c) Phaeophyceae (d) All of the above
3. A plant shows thallus level of organization. It shows rhizoids and is haploid. It needs water to complete its life cycle because the male gametes are motile. Identify the group to which it belongs to [NCERT]  
 (a) Pteridophytes (b) Gymnosperms  
 (c) Monocots (d) Bryophytes
4. A Prothallus is [NCERT]  
 (a) A structure in pteridophytes formed before the thallus develops  
 (b) A sporophytic free living structure formed in pteridophytes  
 (c) A gametophyte free living structure formed in pteridophytes  
 (d) A primitive structure formed after fertilization in pteridophytes

6. When the sperms of *Funaria* and *Pteris* are put together near the archegonia of *Pteris*, only the sperms of *Pteris* readily enter the archegonia and reach the egg. The reason being that [CBSE PMT 1994]
- Sperms of *Funaria* are killed when mixed with sperms of *Pteris*
  - Archegonia of *Pteris* secrete a substance which repels sperms of *Funaria*
  - Archegonia of *Pteris* secrete a chemical substance which attracts sperms of *Pteris* chemotactically
  - Sperms of *Funaria* are less motile
7. Match the following with correct combination
- |    | Column - I        |    | Column - II  |
|----|-------------------|----|--------------|
| A. | <i>Anthoceros</i> | 1. | Walking fern |
| B. | <i>Adiantum</i>   | 2. | Alga         |
| C. | <i>Sargassum</i>  | 3. | Inferae      |
| D. | <i>Asterales</i>  | 4. | Gametophyte  |
|    |                   | 5. | Hornwort     |
|    |                   | 6. | Liverwort    |
- [Kerala PMT 2007]
- A-6, B-5, C-1, D-3
  - A-5, B-4, C-3, D-2
  - A-5, B-1, C-2, D-4
  - A-3, B-2, C-1, D-5
  - A-1, B-4, C-3, D-5
8. Read the following five statements (A-E) and answer as asked next to them
- In *Equisetum* the female gametophyte is retained on the parent sporophyte
  - In *Ginkgo* male gametophyte is not independent
  - The sporophyte in *Riccia* is more developed than that in *Polytrichum*
  - Sexual reproduction in *Volvox* is isogamous
  - The spores of slime moulds lack cell walls
- How many of the above statements are correct [CBSE PMT (Mains) 2012]
- Two
  - Three
  - Four
  - One
9. The ferns in which the entire sporangium develops from a single superficial cell of the sporophyll are known as
- Leptosporangiate
  - Eusporangiate
  - Unisporangiate
  - Mesosporangiate
10. If the haploid number of chromosomes in *Pinus* is 12, the number in its endosperm cells will be [BHU 1994; CPMT 1999; KCET 1999; MP PMT 2002]
- 12
  - 24
  - 36
  - 6
11. "Monkey's puzzle" is a common name for
- Araucaria embricata*
  - Cycas revolute*
  - Pinus longifolia*
  - Gnetum genon*
12. The 13-celled male gametophyte of *Selaginella* shows [CPMT 1999; BHU 2001,03; AIIMS 2001]
- 8 cells of the antheridium + 5 prothallial cells
  - 9 cells of the antheridium + 4 prothallial cells
  - 10 cells of the antheridium + 3 prothallial cells
  - 8 jacket cell + 4 androgonial + 1 prothallial cells
13. Which of the following alga shows heterotrichous habit
- Oedogonium*
  - Chlamydomonas*
  - Ulothrix*
  - Stigeoclonium*
14. The number of antherozoids produced from an antheridium of *Selaginella* is
- 64
  - 256 and above
  - 25 to 50
  - 128 to 256
15. Read the following five statements (A to E) and select the option with all correct statements
- Mosses and Lichens are the first organisms to colonise a bare rock.
  - Selaginella* is a homosporous pteridophyte.
  - Coralloid roots in *Cycas* have VAM.
  - Main plant body in bryophytes is gametophytic, whereas in pteridophytes it is sporophytic.
  - In Gymnosperms, male and female gametophytes are present within sporangia located on sporophyte.
- [AIPMT (Cancelled) 2015]
- (B), (C) and (D)
  - (A), (D) and (E)
  - (B), (C) and (E)
  - (A), (C) and (D)
16. The male cone of *Pinus* is formed of [CPMT 2000; KCET 2000]
- Or
- In *Pinus*, male cone bears a large number of [BHU 2006]
- Anthers
  - Megasporophylls
  - Ligules
  - Microsporophylls
17. Of the following group which secrete and deposit calcium carbonate and appear like corals [Kerala CET 2003]
- Red algae
  - Brown algae
  - Blue green algae
  - All of these
18. The gametophytic generation in pteridophytes is commonly called [KCET 1999; AIIMS 1999]
- Thallus
  - Plant body
  - Prothallus
  - Protonema
19. Which one of the following pairs is wrongly matched [CBSE PMT (Mains) 2012]
- Ginkgo* - Archegonia
  - Salvinia* - Prothallus
  - Viroids - RNA
  - Mustard - Synergids
20. A protective cap or hook like covering on the developing capsule in a moss or liverwort is known as [BHU 2002]
- Spine
  - Calyptra
  - Lodicule
  - Calyptragen
21. Number of cotyledons in *Zea*, *Cycas* and *Pinus* respectively are [BHU 2000]
- 1,1, many
  - 1,2,1
  - 1,1,1
  - 1,2,many
22. Which one of the following is common to multicellular fungi, filamentous algae and protonema of mosses [CBSE PMT (Pre.) 2012]
- Diplontic life cycle
  - Members of kingdom plantae
  - Mode of Nutrition
  - Multiplication by fragmentation
23. A. Heterospory  
B. Seed formation  
C. Fertilization process
- What is appropriate for gymnosperms [RPMT 1997]
- AB true C false
  - BC true A false
  - ABC all true
  - ABC all false

24. Flagellated male gametes are present in all the three of which one of the following sets [CBSE PMT 2007]

- (a) *Anthoceros*, *Funaria* and *Spirogyra*  
 (b) *Zygnema*, *Saprolegnia* and *Hydrilla*  
 (c) *Fucus*, *Marsilea* and *Calotropis*  
 (d) *Riccia*, *Dryopteris* and *Cycas*

25. In *Pinus*, the approximate time for fertilization after pollination is [Pune CET 1998]

- (a) Only a few hours (b) Only a few days  
 (c) Only a few weeks (d) About one year

26. Heteromorphic alternation of generations occurs in [EAMCET 1995]

- (a) *Funaria*, *Spirogyra*, *Selaginella*  
 (b) *Funaria*, *Selaginella*, *Cycas*  
 (c) *Spirogyra*, *Rhizopus*, *Selaginella*  
 (d) *Rhizopus*, *Funaria*, *Spirogyra*

27. Make correct pair

- A. Cyanophyceae a. Green colour  
 B. Chlorophyceae b. Blue green colour  
 C. Phaeophyceae c. Red colour  
 D. Rhodophyceae d. Brown colour

[RPMT 1997]

- (a) Aa, Bb, Cc, Dd (b) Ab, Bc, Cd, Da  
 (c) Ab, Ba, Cd, Dc (d) Ad, Bd, Ca, Db

28. The endosperm of gymnosperm is [CPMT 1993, 99; CBSE PMT 1999; RPMT 2006; Odisha JEE 2012]

- (a) Triploid (b) Haploid  
 (c) Diploid (d) Polyploid

29. In which of the following, multiciliated/multiflagellated antherozoids are present [CPMT 1999; BHU 2003]

- (a) *Riccia* and *Funaria* (b) *Pteris* and *Cycas*  
 (c) *Riccia* and *Cycas* (d) *Marchantia* and *Riccia*

30. When the gametophyte is not formed by spores but by any other part of sporophyte, it is known as [AIIMS 1998]

- (a) Multisporous (b) Polysporous  
 (c) Aposporous (d) Germination

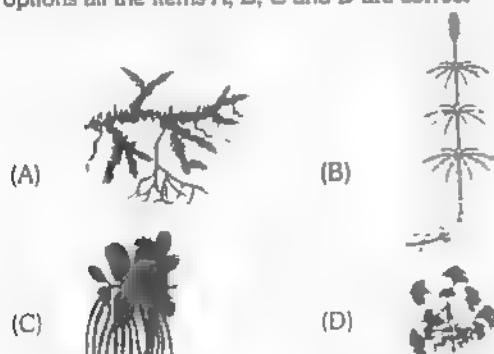
31. A mature ligule, having a prominent basal portion, is called [AIIMS 1998; CPMT 2000; CBSE PMT 2002]

Or

The basal portion of ligule of *Selaginella* is hemispherical and is called

- (a) Trichocyst (b) Heterocyst  
 (c) Rhizophore (d) Glossopodium

32. Examine the figures A, B, C and D. In which one of the four options all the items A, B, C and D are correct



Options:

[CBSE PMT (Mains) 2010]

	A	B	C	D
(a)	<i>Chora</i>	<i>Marchantia</i>	<i>Fucus</i>	<i>Pinus</i>
(b)	<i>Equisetum</i>	<i>Ginkgo</i>	<i>Selaginella</i>	<i>Lycopodium</i>
(c)	<i>Selaginella</i>	<i>Equisetum</i>	<i>Salvinia</i>	<i>Ginkgo</i>
(d)	<i>Funaria</i>	<i>Adiantum</i>	<i>Salvinia</i>	<i>Riccia</i>

33. Match the columns

	Column-I	Column-II
A.	Hornwort	1. Lycopodium
B.	Liverwort	2. Ricciocarpus
C.	Stonewort	3. Anthoceros
D.	Club moss	4. Chara

[AIIMS 2010]

	A	B	C	D
(a)	2	3	4	1
(b)	2	3	1	4
(c)	3	2	1	4
(d)	3	2	4	1

34. Which one of the following is a correct statement

[CBSE PMT (Pre.) 2012]

- (a) Pteridophyte gametophyte has a protonemal and leafy stage  
 (b) In gymnosperms female gametophyte is free-living  
 (c) Antheridiophores and archegoniophores are present in pteridophytes  
 (d) Origin of seed habit can be traced in pteridophytes

35. Read the following statements (A – E) and answer the question which follows them

- (A) In liverworts, mosses and ferns gametophytes are free living  
 (B) Gymnosperms and some ferns are heterosporous  
 (C) Sexual reproduction in *Fucus*, *Volvox* and *Allbugo* is oogamous  
 (D) The sporophyte in liverworts is more elaborate than that in mosses  
 (E) Both, *Pinus* and *Marchantia* are dioecious

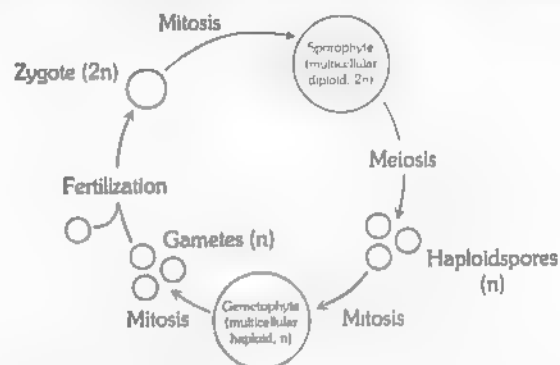
How many of the above statements are correct [NEET 2013]

- (a) Four (b) One  
 (c) Two (d) Three

36. What is common in all the three *Funaria*, *Dryopteris* and *Ginkgo* [NEET (Karnataka) 2013]

- (a) Presence of archegonia (b) Well developed vascular tissues  
 (c) Independent gametophyte (d) Independent sporophyte

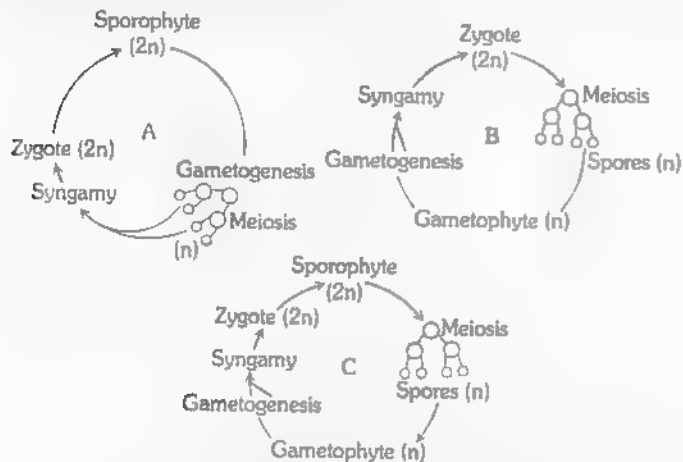
37. The given figure is showing life cycle of a plant if this belongs to life cycle of bryophytes, pteridophytes and gymnosperms, what will be respective A and B in their life cycle [NCERT]



	A	B
(a)	Bryophytes : Pteridophytes : Gymnosperms :	Strobili, capsule cones, sporangia flowers, cones
(b)	Bryophytes Pteridophytes : Gymnosperms	Protonema, gametophores strobili, sporangia flowers, cones
(c)	Bryophytes : Pteridophytes : Gymnosperms .	Capsule, protonema (gametophores) sporangia, cones, sporophyll fertile fronds, megasporangia and microsporangia
(d)	Bryophytes : Pteridophytes : Gymnosperms :	Sporangium, capsule strobili, sporangia flowers, cones



38. Which of the following options are correctly represents the type of life cycle patterns given below [NCERT]



- (a) A – Diplontic, B – Haplontic, C – Haplodiplontic  
 (b) A – Haplontic, B – Diplontic, C – Haplodiplontic  
 (c) A – Haplodiplontic, B – Haplontic, C – Diplontic  
 (d) A – Diplontic, B – Haplodiplontic, C – Haplontic
39. Select the **correct** statement [NEET (Phase-I) 2016]  
 (a) Gymnosperms are both homosporous and heterosporous  
 (b) *Salvinia*, *Ginkgo* and *Pinus* all are gymnosperms  
 (c) *Sequoia* is one of the tallest trees  
 (d) The leaves of gymnosperms are not well adapted to extremes of climate
40. In bryophytes and pteridophytes, transport of male gametes requires [NEET (Phase-I) 2016]  
 (a) Wind (b) Insects  
 (c) Birds (d) Water
41. Select the mismatch [NEET 2017]  
 (a) *Pinus* – Dioecious  
 (b) *Cycas* – Dioecious  
 (c) *Salvinia* – Heterosporous  
 (d) *Equisetum* – Homosporous
42. Life cycle of *Ectocarpus* and *Fucus* respectively are [NEET 2017]  
 (a) Haplontic, Diplontic (b) Diplontic, Haplodiplontic  
 (c) Haplodiplontic, Diplontic (d) Haplodiplontic, Haplontic

## R Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below.

- (a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion  
 (b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion  
 (c) If the assertion is true but the reason is false  
 (d) If both the assertion and reason are false  
 (e) If the assertion is false but reason is true
1. Assertion Biennial plants flower in two year.  
 Reason The biennial plants live for two years.

2. Assertion Bryophytes and tracheophytes have an embryo stage in their life cycle.  
 Reason Embryophyta are terrestrial plants.
3. Assertion Stamens are comparable to microsporophylls.  
 Reason Ovules are comparable to megasporophylls.
4. Assertion Algae and fungi are grouped in thallophyta.  
 Reason Algae and fungi show no differentiation in thallus.
5. Assertion Each group of algae has a characteristic colour.  
 Reason Each group of algae show predominance of one pigment.
6. Assertion Only red algae are able to flourish at the great depth of sea  
 Reason Red algae has the pigments *r*-phycoerythrin and *r*-phycocyanin.
7. Assertion Spermatangium of red algae bears trichogyne.  
 Reason Trichogyne helps in reproduction.
8. Assertion *Spirogyra* is slippery in touch.  
 Reason *Spirogyra* consists a gelatinous sheath.
9. Assertion Isogamy is a primitive type of sexual reproduction.  
 Reason The gametes are of different sizes.
10. Assertion Angiosperms lack flagellate male gametes.  
 Reason Sperms are not dependent on water for fertilization.
11. Assertion Fertilized ovule forms seed.  
 Reason Ripened ovary forms fruit.
12. Assertion Pyrenoids are utilised during starvation.  
 Reason Pyrenoids are proteinaceous bodies.
13. Assertion In green algae, the eye-spot is present in the cell.  
 Reason Eye-spot is meant for respiration.
14. Assertion *Chlorella* could be utilised to keep the air pure in space vehicles.  
 Reason The space travelers feed on *Chlorella* soup.
15. Assertion Flower is aggregation of sporophylls.  
 Reason Sporophylls are modified in angiosperms.
16. Assertion *Chlorella* could serve as a potential source of food and energy.  
 Reason When dried, *chlorella* has 15% protein, 45% fat, 10% carbohydrate, 20% fibre, and 10% minerals and vitamins. [AIIMS 2009]
17. Assertion *Spirogyra* shows haplontic life cycle.  
 Reason Zygotic meiosis occurs in *Spirogyra*.
18. Assertion Red algae contribute in producing coral reef.  
 Reason Some red algae secrete and deposit calcium carbonate over their walls. [AIIMS 2004]
19. Assertion The sex organs in the bryophytes are jacketed.  
 Reason Bryophytes are land plants.
20. Assertion All bryophytes are land dwellers.  
 Reason Water is necessary to complete their life-cycle.

- 21. Assertion** The bryophytes exist in two phases – gametophyte and sporophyte.  
**Reason** The sporophyte is nutritionally independent.
- 22. Assertion** Unlike thallophytes, bryophytes show formation of embryo.  
**Reason** The embryo gives rise to gametophyte plant of bryophytes.
- 23. Assertion** Bryophytes possess archegonium as a female sex organ.  
**Reason** Algae also possess the archegonium.
- 24. Assertion** The embryo of bryophyte is independent.  
**Reason** The zygote of thallophyte is dependent.
- 25. Assertion** Liverworts fail to spread to a new locality through fragmentation.  
**Reason** Gemmae are helpful in propagating liverworts in different locality.
- 26. Assertion** *Pinus* displays the alternation of generations.  
**Reason** The gametophyte is dependent upon the sporophyte phase.
- 27. Assertion** *Pinus* embryo has two cotyledons.  
**Reason** *Pinus* shows polyembryony.
- 28. Assertion** The female cones take much time to mature.  
**Reason** The seeds are shed when the cone is 22 months old.
- 29. Assertion** The female cones are same in number as male cones.  
**Reason** Male and female cones appears alternately on the same branch of the *Pinus*.
- 30. Assertion** Sperms of *Riccia* are biflagellate.  
**Reason** Sperms show swimming nature.
- 31. Assertion** The sporogonium of *Riccia* is the simplest among the liverworts.  
**Reason** Sporophyte consists of capsule only.
- 32. Assertion** The young stem of *Funaria* is photosynthetic.  
**Reason** It contain hydroids.
- 33. Assertion** *Pinus* is monoecious.  
**Reason** Each sporophyll bears only one microsporangia.
- 34. Assertion** *Funaria* multiplied vegetatively by means of bulbils.  
**Reason** Bulbils and tubers are two different structures.
- 35. Assertion** Gemmae formation in *Funaria* occurs in favourable condition.  
**Reason** The gemmae form on the stem and leaves.
- 36. Assertion** *Funaria* is monoecious.  
**Reason** Cross fertilization occurs in *Funaria*
- 37. Assertion** Antheridia of *Funaria* are sunk in pit.  
**Reason** Its antheridial cluster is surrounded by perigonal leaves.
- 38. Assertion** The peristome is a fringe of teeth-like projections found at the mouth of the capsule  
**Reason** It may be of two types nematodontous and orthodontous.
- 39. Assertion** The mesophyll of *Pinus* shows no distinction as mesophyll and palisade.  
**Reason** Parenchymatous cells are present in mesophyll of *Pinus*.
- 40. Assertion** *Pinus* shows formation of annual rings.  
**Reason** *Pinus* grows in area of environmental fluctuation.
- 41. Assertion** Mosses are used as pollution indicators.  
**Reason** They absorb metals.
- 42. Assertion** Mosses are evolved from algae.  
**Reason** Protonema of mosses is similar to some green algae. [AIIMS 2001, 13]
- 43. Assertion** The sorus of *pteridium* is of coenosorus type.  
**Reason** *Pteridium* lacks sori.
- 44. Assertion** Coenosorus lacks true indusium.  
**Reason** Indusium covers sori.
- 45. Assertion** Ramenta are scales which cover young rhizome and leaves of *Dryopteris*.  
**Reason** *Pteridium* lacks rementa.
- 46. Assertion** The scale leaves on the long shoots are called cataphylls.  
**Reason** Cataphylls lack mid rib.
- 47. Assertion** Both bryophytes and pteridophytes contain well-developed antheridia.  
**Reason** Biflagellate sperms are formed by their antheridia.
- 48. Assertion** Water is not required for fertilization process in ferns.  
**Reason** Malic acid of archegonial neck attracts antherozoids.
- 49. Assertion** Sporophytes of pteridophyta are dominant individual.  
**Reason** They do not show the formation of true root.
- 50. Assertion** In gymnosperms, plants show well-developed vessels and fibres.  
**Reason** Companion cells are absent in gymnosperm.
- 51. Assertion** In leptosporangiate development, sporangia are formed from a group of initials.  
**Reason** Eusporangiate development of sporangia starts from single initial.
- 52. Assertion** *Adiantum caudatum* is called walking fern.  
**Reason** It can reproduce by its leaf tips.
- 53. Assertion** Gymnosperms seeds are naked.  
**Reason** They lack ovary wall
- 54. Assertion** *Pinus* has a pyramidal appearance.  
**Reason** The older parts of long shoot have scars of fallen dwarf shoots.
- 55. Assertion** The female cone of *Cycas* is not true cone.  
**Reason** Its formation checks the growth of the stem.
- 56. Assertion** All living species of *Cycas* are dioecious  
**Reason** *Cycas* contains male and female cones on the same plant.
- 57. Assertion** The male of *Cycas* change in size when the microspores became mature.  
**Reason** The microspores are dispersed by wind.

# Answers

## Algae (General)

1	a	2	a	3	a	4	a	5	c
6	d	7	d	8	b	9	e	10	b
11	a	12	b	13	c	14	a	15	a
16	c	17	c	18	a	19	a	20	a
21	b	22	b	23	d	24	d	25	c
26	d	27	e	28	c	29	c	30	d
31	a	32	b	33	c	34	a	35	d
36	c	37	d	38	b	39	a	40	c
41	b	42	b	43	a	44	c	45	d
46	a	47	a	48	d	49	a	50	e
51	a	52	d	53	d	54	a	55	c
56	d	57	d	58	d	59	d	60	d
61	a	62	a	63	d	64	c	65	b
66	b	67	d	68	b	69	c	70	a
71	a	72	d	73	d	74	b	75	d
76	a	77	b	78	c	79	b		

## Spirogyra and Ulothrix

1	b	2	c	3	b	4	a	5	d
6	d	7	b	8	a	9	a	10	a
11	b	12	d	13	a	14	b	15	d
16	c	17	d	18	a	19	a	20	b
21	b	22	b	23	a	24	a	25	c
26	b	27	c	28	a	29	c	30	a
31	b		b	33	c	34	a	35	a
36	b	37	a	38	a	39	d	40	a
41	d	42	c	43	d				

## Bryophytes (General)

1	d	2	d	3	c	4	b	5	d
6	c	7	b	8	c	9	a	10	a
11	d	12	d	13	c	14	b	15	b
16	c	17	d	18	c	19	a	20	d
21	b	22	a	23	a	24	c	25	b
26	d	27	d	28	c	29	d	30	c
31	b	32	a	33	c	34	d	35	c
36	d	37	a	38	a	39	b	40	c
41	c	42	d	43	a	44	a	45	a
46	a	47	c						

## Funaria and Riccia

1	c	2	a	3	c	4	c	5	b
6	d	7	a	8	b	9	c	10	b
11	b	12	c	13	c	14	a	15	c
16	d	17	b	18	d	19	a	20	b
21	d	22	b	23	c	24	b	25	c
26	b	27	a	28	d	29	c	30	c
31	d	32	a	33	c	34	d	35	c
36	a	37	d	38	b	39	b	40	c
41	b	42	b	43	c	44	d	45	b
46	a								

## Pteridophytes (General)

1	b	2	c	3	a	4	d	5	d
6	b	7	c	8	b	9	a	10	c
11	a	12	d	13	b	14	a	15	b
16	a	17	c	18	b	19	c	20	a
21	d	22	b	23	a	24	a	25	a
26	c	27	a	28	b				

## Pteridium, Pteris, Dryopteris

1	d	2	d	3	c	4	a	5	d
6	a	7	c	8	b	9	b		c
11	a	12	b	13	a	14	c	15	c
16	a	17	d	18	b	19	b	20	c
21	c	22	a	23	d	24	a	25	a
26	d	27	c	28	c	29	d	30	b
31	c	32	d	33	b	34	b	35	d
36	a	37	a	38	b	39	c	40	d
41	d	42	a	43	d	44	b	45	a
46	a								

## Selaginella

1	b	2	a	3	c	4	c	5	a
6	c	7	b	8	b	9	d	10	d
11	b	12	a	13	c	14	b	15	a
16	a	17	c	18	b	19	c	20	a
21	b	22	b	23	a	24	d		

## Gymnosperms (General)

1	a	2	c	3	d	4	a	5	d
6	d	7	c	8	d	9	b	10	c

## 170 Plant Kingdom

11	d	12	d	13	b	14	a	15	a
16	c	17	a	18	d	19	d	20	d
21	b	22	a	23	d	24	c	25	d
26	d	27	c	28	c	29	b		

### Pinus

1	c	2	b	3	c	4	d	5	d
6	a	7	c	8	c	9	d	10	c
11	b	12	a	13	b	14	d	15	b
16	c	17	a	18	b	19	d	20	b
21	b	22	c	23	a	24	a	25	d
26	d	27	b	28	c	29	b	30	a
31	b	32	a	33	a	34	c	35	a
36	b	37	a	38	b	39	d	40	c
41	c								

### Cycas

1	c	2	a	3	c	4	a	5	d
6	a	7	a	8	a	9	b	10	c
11	c	12	d	13	b	14	d	15	c
16	d	17	b	18	d	19	b	20	a
21	a	22	a	23	d	24	c	25	b
26	d	27	d	28	d	29	a	30	b
31	a	32	c	33	a	34	d	35	d
36	b	37	d	38	b	39	c	40	b
41	c	42	d	43	c				

### Angiosperms

1	a	2	d	3	a	4	b	5	c
6	d	7	a	8	b	9	d	10	b
11	d	12	b	13	b	14	a	15	a
16	d								

### NCERT Exemplar Questions

1	c	2	c	3	d	4	c	5	d
6	c	7	a	8	d				

### Critical Thinking Questions

1	b	2	d	3	b	4	b	5	c
6	c	7	c	8	d	9	a	10	a
11	a	12	d	13	d	14	d	15	b
16	d	17	a	18	c	19	b	20	b
21	d	22	d	23	c	24	d	25	d

26	b	27	c	28	b	29	b	30	c
31	d	32	c	33	d	34	d	35	d
36	a	37	c	38	a	39	c	40	d
41	a	42	c						

### Assertion and Reason

1	b	2	b	3	b	4	a	5	a
6	a	7	e	8	a	9	c	10	a
11	b	12	b	13	c	14	b	15	b
16	c	17	a	18	a	19	a	20	e
21	c	22	c	23	c	24	d	25	b
26	b	27	e	28	b	29	d	30	a
31	a	32	b	33	c	34	c	35	e
36	b	37	e	38	b	39	b	40	a
41	a	42	a	43	c	44	b	45	b
46	d	47	d	48	e	49	c	50	e
51	d	52	a	53	a	54	b	55	c
56	c	57	b						

## AS Answers and Solutions

### Algae (General)

- (a) M.O.P. lyenger of Madras is regarded as the father of Indian phycology. He discovered *Fritschella*, a heterotrichous terrestrial alga.
- (a) The study of algae is called algology or phycology (Gr. *phykos* = algae) and its expert as phycologist / algologist.
- (a) F.E. Fritsch (1935) divided algae into following eleven classes in his book "Structure and Reproduction of the Algae", mainly on the basis of pigmentation, reserve food and flagellation, thallus structure, modes of reproduction and life cycles and he is known as father of algae.
- (d) Agar-agar is a jelly like substance. It is a non-nitrogenous carbohydrate consisting of two polysaccharides namely agarose and agarpectin. It is obtained from several red algae. e.g., *Gracillaria*, *Gelidium*, *Gigartina*. It was discovered by Lady Hesse and used by Robert Koch to solidify culture medium
- (a) Different type of colour in Algae are due to different pigmentations and it provides a strong base to classify the Algae.
- (c) *Cephaleuros virescens* is a member of class chlorophyceae and cause disease red rust of tea leaf (*Thea sinensis*).

22. (b) *Spirulina uiridisma* : It is a convoluted cyanophycian alga, which has 60% protein contents.
24. (d) All are eukaryotes except *Anabaena*. The latter is prokaryotes where true nucleus is absent.
28. (c) Many algae important constituent of human food in future because the algae can grow easily and obtained protein, lipid carbohydrates and vitamins. e.g., *Chlorella*, *Ulva*.
32. (b) Pyrenoids are the rounded bodies found in the chloroplast of green algae and are the centres of conversion of glucose to starch and also collection of starch.
33. (c) Because algae and fungi are the members of thallophyta.
34. (a) *Chlorella vulgaris* : This is the source of protein. This is rounded unicellular algae related to class chlorophyceae.
36. (c) Hypnospores are thick walled non-motile spores formed to tide over unfavourable condition. They germinate on the arrival of favourable condition ns. e.g., *Chlamydomonas*, *Ulothrix*.
38. (b) In dry conditions, zoospores get surrounded by mucilaginous sheath. This is known as Palmella stage. Under favourable conditions each zoospore gives rise to a new plant e.g., *Chlamydomonas*.
41. (b) In Rhodophyceae reserve food products are polysaccharides i.e., Floridean starch (which stains red with iodine solution) and also soluble sugar called floridoside.
43. (a) The larger (giant) parenchymatous forms of brown algae called kelps or sea weed or trees of seas or forest of sea Sea weed may be marine.
44. (c) *Chlorella* could be used to provide  $O_2$  during space flight trips. The alga can reuse  $CO_2$  during the process of photosynthesis and release  $O_2$  for the use by Astronauts
45. (d) Alginic acid is a non sulphated phycocolloid extracted from middle lamella/cell walls of *Laminaria*, *Lessonia*, *Fucus* etc.
46. (a) Algae differ from bryophyta because in algae sex organs are usually non-jacketed and in bryophyta sex organs are jacketed with sterile jacket.
47. (a) Parasitic algae like *Cephaleuros virescens* (green alga) causes red rust of tea leaves and *C. coffea* attacks coffee leaves It is red due to haematochrome.
51. (a) *Laminaria* kelp is the source of iodine.
52. (d) Carragenin is obtained from chondrus. It is member of Rhodophyceae.
54. (a) Stomata are originated with the origin of bryophytes (Amphibian group). Algae are primitive than bryophytes
55. (c) Chlorophyll a and b pigments are found in chlorophyceae.
57. (d) Fusion of gametes results in the formation of zygote, which by secreting a thick wall acts as perennating spore (zygospore) and helps in perennation, dispersal and multiplication.
59. (d) These are pteridophytes
61. (a) In algae reserve food material is mainly starch.
64. (c) A large amount of iodine is extracted from kelps (brown sea weeds) like *Laminaria*, *Ecklonia* etc.).
65. (b) *Volvox* hollow ball like colony with a fixed number of cells is called coenobium
67. (d) Oogamy is most advanced type of reproduction in which male gamete is motile smaller and non food storing called antherozoid while female gamete is food storing, nonmotile larger called oogonium.
69. (c) Grana is absent in green algae.
76. (a) Nucule/oogonium/upper sex organ  
Globule/antheridium/lower sex organ.
77. (b) *Anabaena* – Non flagellated male gamete  
*Spirogyra* – Aplanogamy  
*Polysiphonia* – Non motile spermatia  
*Ectocarpus* – Pear shaped motile male gametes
78. (c) Algin is obtained from brown algae and carrageenin from red algae

### Spirogyra and Ulothrix

2. (c) *Spirogyra* increases its body length because every cell of the filament is capable of growth division and self maintenance (every cell has nucleus).
3. (b) Sexual reproduction in *Spirogyra* involves the fusion of two morphologically identical but physiologically dissimilar nonciliated gametes.
4. (a) *Spirogyra* is a free floating, filamentous, green, freshwater alga which is popularly called pond silk, hair of princess because its filaments are slimy to touch and shine in water.
5. (d) Zygospore under goes meiosis to form a new filament.
6. (d) Because single zygospore produce four spores but three are diminished and remaining one develop into a new plant.
7. (b) *Spirogyra* gives silky feeling on touching.
10. (a) Zygospore undergoes zygotic meiosis and forms 4 haploid nuclei of these three degenerate. So one haploid nuclei take part and one new filament is formed.
11. (b) In scalariform conjugation, two filament come to lie parallel and appressed. Their opposite cells develop conjugation tube. The conjugation tube between the two filaments look like a ladder.
14. (b) Sexual reproduction of *Spirogyra* is physiological anisogamous.
15. (d) Sexual reproduction in *Spirogyra* can be described as fusion of two morphologically identical, but physiologically dissimilar gametes.
16. (c) Rarely three filaments may take part in scalariform conjugation. Here the central filament shows relative sexuality and behave as male to one and female to other so that zygospore are formed in either central or lateral filaments.
18. (a) On failure in fusion of two gametes, both the gametes develop into azygospores. Under unfavorable condition, the filament of *S. varians* placed in sugar solution develop parthenospore or azygospore.

19. (a) Each cell of *Spirogyra* is surrounded by two layered cell wall. Its inner layer is made up of cellulose and outer layer is made up of pectose but quantity of cellulosic substances is high in comparison to pectose.
21. (b) The filament showing lateral conjugation are homothallic because both male and female gametes are found in same filament.
23. (a) Filamentous alga with flagellated reproductive stage represented by gametes.
24. (a) Each cell contains a single chloroplast in *Ulothrix*.
25. (c) *Ulothrix* is green algae.
27. (c) *Ulothrix* is unbranched filament, consisting of numerous cylindrical cells joined end to end.
28. (a) *Mucor* have multinucleate gametangia
29. (c) Favourable conditions each zygote germinates to produce 4–16 meiospores (zoospores or aplanospores). The first division of diploid zygotic nucleus is meiosis. The meio-zoospores or meioaplanospores germinate to produce new filaments.
31. (b) *Spirogyra* shows isogamy with non-flagellated gametes
32. (b) Chloroplast contains few pyrenoids (1–3) for starch storage.
33. (c) Iyenger (1958) reported direct lateral conjugation in *Spirogyra jogensis*.
34. (a) *Ulothrix* is unbranched filament and attached to stone and submerged bodies (fixed floating)
35. (a) A spore of *Spirogyra* sp. after resting period (zygospore) is haploid because meiosis occurs in zygospore
36. (b) Plant body of *Spirogyra* is haploid but after gametic fusion, diploid zygospore is formed, thus zygotic meiosis takes place
38. (a) Life cycle in *Spirogyra* is haplontic as dominant phase in life cycle is haploid ( $n$ ) and diploid phase is represented by only zygospore and it undergoes meiosis.
39. (d) Chloroplast in *Ulothrix* is girdle or ring shaped (*U. zonata*) or collar shaped.
40. (a) *Ulothrix* produces isogametes i.e., gametes are biflagellate and similar (size, shape) but different in nature.
41. (d) Basal cell is nongreen but has nucleus and cytoplasm. Its presence show beginning of division of labour.
43. (d) The gametes are motile and biflagellate.
11. (d) Because club moss is pteridophyte while Reindeer moss and Irish moss are lichens
12. (d) In Bryophytes vascular tissue (i.e., xylem and phloem) are completely absent. Water and nutrients enter in cell by diffusion when in pteridophytes vascular tissue consists of xylem (without true vessels) and phloem (without companion cells).
14. (b) The sporogonium of *Marchantia* is differentiated into foot, seta and capsule. Capsule contains elaters ( $2n$ ). Elaters are diploid, spindle shaped hygroscopic elongated structures with 2 spiral bands.
15. (b) The main plant of Bryophyte is gametophyte.
16. (c) Bryophyta are the most simple and primitive group of embryophyta. It includes app. 840 genera and 23,500 species.
17. (d) *Sphagnum* is used as fuel. *Sphagnum* has the capacity to retain water for long periods and as such is used to cover the plant roots during transportation. It is also used in seed beds because of its high water retention capacity.
18. (c) The female sex organ is archegonia. It is flask shaped structure distinguishable into a long neck and a globular swollen venter.
19. (a) Gametophytes are reduced and few celled in all vascular plants.
21. (b) Stalk bearing archegonial cluster at tip in *Marchantia* thallus.
22. (a) In bryophytes, water is essential for fertilization because antherozoids are flagellated or ciliary structure which represent the aquatic origin of bryophytes.
23. (a) Saprophytic bryophytes are *Buxbaumia aphylla*. Which are nongreen growing on rotten wood.
24. (c) In bryophytes, gametophyte is dominant phase and sporophyte is developed on this phase which is partially depends for food on gametophyte.
25. (b) Bryophyta grow in moist and shady places. More humid conditions are found in Western Himalayas.
26. (d) In Bryophytes, sporophyte is never independent but it is parasitic over gametophytic plant either partially for water and mineral supply or wholly for organic food.
27. (d) Male sex organ is globular called antheridium and female sex organ is called archegonium which is flask shaped. These are look like green in colour because they contain chloroplast. True roots, stem and leaves absent in Bryophytes.

### Bryophytes (General)

2. (d) Newzealand genera of moss *Dawsonia* which measures 60 cms in height
5. (d) Venter is present in archegonia just above the egg.
7. (b) The vascular tissue (i.e., xylem and phloem) are completely absent water and nutrients enter the cell by diffusion. Sporangium produces spores by meiosis. The zygote develops to form an embryo which produces the sporophyte.
8. (c) They are called pollution indicators. They prevent soil erosion by running water.
9. (a) Species of *sphagnum*, a moss provides peat that have long been used as fuel.
30. (c) The main plant of bryophyta is gametophyte. Gametophytic stage is independent.
31. (b) Term Bryophyta was coined by Robert Braun in 1864 but he included algae, fungi, lichens and mosses under it.
33. (c) Female sex organ is called archegonium which is flask shaped with a tubular neck and a swollen venter.
34. (d) Thallus of *Anthoceros* shows symbiotic association with a nitrogen fixing blue green alga i.e., *Nostoc*.
35. (c) Below neck canal cells, there is a venter canal cell and an egg cell (oosphere) in the venter. Egg cell behaves as nonmotile female gamete.

37. (a) The number of chromosomes of the second generation will be same because no reduction division take place.
40. (c) The chloroplast of *Anthoceros* contains a unique feature 'pyrenoid' made up of 25–30 discoid or spindle shaped bodies.
43. (a) The archegonial venter forms a protective covering around the embryo called calyptra.

### Funaria and Riccia

1. (c) Stomata are primitive because guard cells are not found. Only stomatal pores are found.
3. (c) Protonema : It is green, septate, filamentous algae like which is borne after the germination of moss haploid spores.
4. (c) The sporophytic is parasitic over gametophyte. Thus there is heteromorphic or heterologous alternation of generations in *Riccia*. So life cycle in *Riccia* is diplohaplontic.
5. (b) *Funaria* is attached to substratum by rhizoids are branched, multicellular, arise from base of axis and have oblique septa to increase.
7. (a) When the capsule approaches maturity the sporogenous cells cease to divide, separate from one another and they are known as spore mother cells. Each spore mother cell undergoes two successive divisions, first of which is meiotic and forms four spores with haploid number of the chromosomes.
8. (b) Protonema is formed after germination of moss capsule spores
9. (c) Life cycle of *Funaria* is not completed without water because antherozoids swim across the film of water and antherozoid fuse with the single egg to produce zygote ( $2n$ ).
10. (b) Autotrophic nutrition is a common feature to gametophytes and sporophytes of mosses and fern because chlorophyll containing cells found in both which are assimilatory in function.
11. (b) Capsule wall is a diploid part of sporophyte, if protonema is develops from its cells, it must be diploid.
13. (c) Foot, seta and central sterile portion of theca is called columella found in *Funaria*. Elaters are absent in *Funaria*, *Sphagnum*, *Polytrichum*, *Riccia*, etc. They are the characteristic features of *Marchantia*, *Pellia*, *Porella*, etc
14. (a) Dispersal of spores take place due to hygroscopic nature of peristomial teeth.
15. (c) Annulus assists in dehiscence of capsule.
16. (d) The neck is several cells high and is made up of six vertical rows of cells. It contains six or more elongated uninucleate neck canal cells.
17. (b) Monoecious means both male and female sex organs are borne on the same plant body and autoecious means green photosynthetic.
19. (a) In *Funaria* fully developed sporophyte (sporangium) is made of three regions, i.e., Basal foot, seta and capsule.
20. (b) The axis has a central conducting strand of slightly thick walled parenchymatous elongated dead cells called hadrom.
22. (b) Leafy gametophyte develop from buds produced on protonema and is made up of axis with spirally arranged leaves, leafy gametophyte bears male and female sex organs.
23. (c) Apophysis is basal sterile portion of capsule in continuation with seta. In capsule of *Funaria* stomata present only in apophysis.
24. (b) Peristome teeth : Total 32 in two rows 16+16, outer 16 are thick bigger in size while inner 16 are smaller and thin. Teeth help in dispersal of spore filled in sporangium of capsule of *Funaria*.
25. (c) In *funaria* sex organs develop at tip stem antheridia develop on male branch and archegonia on female branch.
26. (b) The antherozoids in *Funaria* are anteriorly biflagellated coiled structures.
28. (d) On the lower portion of leafy gametophore, there are present branched, multicellular rhizoids with oblique septa.
29. (c) In *Funaria* central sterile portion of theca is called columella
30. (c) Female sex organs (archegonia) are borne at the tip of female branch which is larger than male shoot.
31. (d) In capsule of *funaria* stomata are present only in apophysis.
32. (a) An archegonium of *Riccia* has neck encloses 4–6 neck canal cells. Venter wall is single layered and encloses one venter canal cell and one egg cell (oosphere).
35. (c) The lower surface of *Riccia* bears two type of unicellular rhizoids, smooth walled and tuberculate and help in fixation.
36. (a) Gametophyte stage of *funaria* is haploid because the main plant body is gametophyte
38. (b) Sex organs are multicellular, jacketed and embedded in thallus on dorsal side.
40. (c) In *Riccia* antherozoids may enter into the archegonium and fuse with single egg to form zygote ( $2n$ ), which is ending of gametophyte phase.
41. (b) Spore is the first cell of gametophytic generation In *Funaria* the spore germinates to form protonema.
43. (c) The main plant body of *Riccia* is gametophytic ( $n$ ), which is thallose, i.e., having no true roots, stem and leaves.
44. (d) Meiosis takes place in spore mother cells which results four haploid spores are formed.
45. (b) The peristome is distinguishable into two whorls of radially arranged peristomial teeth.
46. (a) Protonema is the branched filamentous portion which is produced by germination of spores.

### Pteridophytes (General)

1. (b) Pteridophytes are also known as 'Vascular cryptogams' The term 'Cryptogams' is made of 2 Greek word, i.e., Kryptose, hidden + gamous, wedded, i.e., these are the plants which reproduce by means of spores and do not produce seeds.

2. (c) Birbal Sahani was a famous Indian palaeobotanist. He established famous Birbal Sahani institute of paleobotany in Lucknow (UP) and described *Williamsonia seawardiana*.
5. (d) Due to protandrus (maturation of antheridia before Archegonia) condition archegonia of same thallus do not accept the antherozoids of same thallus. Therefore self fertilization is not possible in Pteridophytes or vascular cryptogames.
8. (b) The club mosses (division Lycophyta) are now limited to representatives a few centimeters in height. Their leaves are small and scale like, resembling the leaf like structures of mosses, club mosses of the genus *Lycopodium*, commonly known as ground pine, form a beautiful ground cover in some temperate coniferous and deciduous forests.
9. (a) Gametophyte of fern is exosporic, flat, green, autotrophic, cordate (Heart shaped), multicellular, short lived, small reduced, dorsiventral, free living independent, nonvascular gametophyte called prothallus.
10. (c) Require water for fertilization as their sperms are motile.
12. (d) Botanical snake : The leaves of "*Ophioglossum*" pteridophyte is like hood of black snake cobra.
13. (b) Heterosporous pteridophytes (e.g., *Isoetes*, *Selaginella*, *Marsilea* etc.) produce unisexual (dioecious) gametophytes. The development of gametophyte is endosporic (grow within spore wall).
17. (c) Pteridophytes are first vascular land (tracheophytes) to have independent, sporophyte diploid plant body with true root, stem and leaves.
18. (b) Sorus (sori = plural) : It is a group of sporangia attached on placenta in ferns.
19. (c) In xylem, vessels are absent and in phloem, companion cells are absent. *Selaginella* and *Equisetum* are exception where vessels are present.
23. (a) Apospory was first observed by Druery (1884) in *Athyrium filix-femina*. Apospory is the formation of complete embryo sac from the sporophytic cell without meiosis so that the gametophyte remains diploid.
24. (a) Seed habit are fulfilled by few pteridophytes like *Selaginella rupestris*, *S. monospora*, *Marsilea* and *Isoetes*.
25. (a) *Ginkgo* is a Gymnosperm.
26. (c) They along with cycadofilicales are chief coal formers. The age of great coal forming forest belong to this period (carboniferous period). India coal belongs to permian period.
27. (a) Apogamous cells are part of gametophyte, thus they are haploid.
28. (b) The central pith is surrounded by xylem, phloem, pericycle and endodermis. The phloem occurs only outside the xylem e.g., *Osmunda*.

### Pteridium, Pteris, Dryopteris

1. (d) In *Pteridium*, male and female sex organs are developed on one gametophyte.
2. (d) Ferns exhibit diplohaplontic life cycle and heteromorphic alternation of generations. The sporophytic and gametophytic phase are morphologically, functionally and cytologically distinct and occur in alternate manner due to meiosis and fertilization.
3. (c) Antheridium producing about 32 antherozoids. Each antherozoid is large uninucleate coiled and multiflagellate.
4. (a) Eusporangiate type of sporangium develops from a group of superficial initials. They divide periclinally into outer and inner.
6. (a) A dictyostele consisting of two or more concentric rings of meristemes. e.g., *Pteridium aquilinum*.
7. (c) In *Dryopteris*, true indusium is present because this arises from placenta (placental tissue) from which sporangia arise.
8. (b) Sori are linear and submarginal in *Pteris* and *Pteridium* and median abaxial (lower) in *Dryopteris*.
9. (b) Inside the sporangium, there are 16 spore mother cells which on meiosis (reduction division) produce 64 spores.
10. (c) In ferns, spores germinate to form a prothallus.
11. (a) They develop a thickening along their radial and inner tangential walls. This layer is called annulus.
13. (a) Neck is made up of 4 vertical rows of cells. Slightly curved and encloses a neck canal cell which is binucleated.
14. (c) Younger parts of leaves and rhizome are surrounded by brown hairy structures called scales (ramenta).
15. (c) In *Dryopteris* true indusium (A specially developed structure) is present.
21. (c) Dominant stage of fern is sporophyte which is always a diploid structure.
23. (d) Gametophyte is free living, photoautotrophic thalloid, also called prothallus. Prothallus bears rhizoids, antheridia and archegonia on its under surface.
24. (a) Young leaves show circinate ptyxis (venation) (water spring like coiling with the apex in the centre of the coil) to protect tip of frond.
25. (a) Fern prothallus bears male and female sex organs both.
26. (d) On sporophylls either on dorsal or on ventral side bear sporangium e.g., *Pteris*, *Dryopteris* etc. Leaves are megaphylls showy feather like and called fronds.
28. (c) Foot is formed first, which absorbs water, minerals from prothallus.
29. (d) Ferns are generally the first colonizers of burnt down forest area. This is due to persistence of their underground rhizomes while the above ground parts get burnt up.



30. (b) Antheridial Jacket is single layered and 3-celled.
31. (c) The number of spores per sporangium are fixed in every species and 64 is the maximum number of spores in sporangium.
35. (d) Ramenta : It is hairy structure which cover juvenile leaves in ferns.
36. (a) No pollen tube to carry sperms.
37. (a) Dictyostele : A siphonostele perforated by several overlapping leaf gaps. Each separate strand is called meristele. e.g., *Dryopteris*, *Pteridium*, *Pteris* etc.
38. (b) Spores of ferns are always haploid so they represent gametophytic stage.
40. (d) Apogamy : Origin of haploid plant (rare) in pteridophytes e.g., from prothallus cells.
42. (a) The plants of pteridophytes are sporophytes. They reproduce asexually by forming spores in sporangia.
43. (d) Prothallus is haploid.
44. (b) Annulus controls and assists in spore dispersal by losing water. Annulus also helps in the ejection of spores with force like a sling.
45. (a) Sporangia develop in groups called sori. Sori develop on the under surface of leaves and leaflets, laterally or marginally.
46. (a) Each sporangium has a multicellular stalk and a biconvex capsule.
9. (d) Heterosporous condition (Produce of two kind of spores i.e., Megaspore and microspore) found in *Selaginella* and Homosporous conditions (Produce one kind of spore) found in *pteris* (fern).
10. (d) Williams, Goebel and Bower regard it as an intermediate structure between root and shoot hence an "Organ sui-gensis".
11. (b) Trabeculae endodermis : Endodermis having air chambers. The endodermis except in xerophytic species (*S. lepidophylla* and *S. rupestris*) is interrupted by large intercellular spaces. This is called the trabeculated endodermis.
12. (a) *Selaginella* is mainly found in damp shaded places. A few species are xerophytic (e.g., *S. lepidophylla*, *S. pilifera*, *S. bryopteris*).
13. (c) In *Selaginella*, sporophytic and gametophytic generation are morphologically as well as genetically differ
15. (a) Roots present in *Selaginella* and rhizoids present in *Funaria*.
16. (a) In male gametophyte the first division leads to formation of a small prothallial cell and a large antheridial cell.
18. (b) A flap like outgrowth is present at the base on adaxial side called ligule. It may be fan-shaped or tongue shaped or lobed. Such leaves are called ligulate.
19. (c) The microspores on germination forms the male gametophyte and the megaspore forms the female gametophyte.
22. (b) The main plant body of *selaginella* sp. is sporophyte which is diploid in condition.
23. (a) In dry conditions, the plant rolls up in to a compact ball and during the rainy conditions the ball on absorbing moisture becomes green again. Such plants are called resurrection plants.
24. (d) Reduction division or meiosis is called as sporic meiosis and is specific type met within pteridophytes.

### Selaginella

1. (b) *Selaginella* show many of the several adaptations required to produce a seed. They are collectively called seed habit of *Selaginella*.
- (1) Presence of heterospory.
- (2) Retention of megaspores inside megasporangium in *S. opus* and *S. rupestris*.
- (3) Formation of two types of gametophytes etc.
2. (a) The four megaspores derived from a megaspore mother cell may not always be functional. e.g., In *S. rupestris* single megaspore is functional.
3. (c) The endodermis is interrupted by large intercellular spaces. This is called the trabeculated endodermis (modified endodermal cell). This layer, due to presence of casparian strips is regarded as endodermis.
4. (c) Stele has polystelic structure with xylem in the center, phloem on the outside and pericycle covering the latter in *Selaginella*.
5. (a) Ramenta or scales are found in *Pteris*, *Dryopteris* (fern).
6. (c) Sperms (antherozoids) of *Selaginella* are 128-256 in number and biflagellated sickle shaped (curved).
7. (b) Nucellus is the megasporangium of *Pinus*.

### Gymnosperms (General)

5. (d) Therophytes are those plants that survive in winter as a seed and complete their life cycle between the spring and autumn
7. (c) Archegonia is found in bryophytes, pteridophytes and gymnosperms and antheridia occurs in bryophytes and pteridophytes
8. (d) Gymnosperms are perennial trees and shrubs and woody large trees.
9. (b) Anemophily or wind pollination occurs in gymnosperms.
15. (a) Canada Balsam is used as a mounting for microscopic studies. The source is *Abies balsamea*

16. (c) The foliage leaves do not have lateral veins. Instead, transfusion tissue (hydrostereom) occurs internally for lateral transport.
19. (d) (a) Cycadophyta → Fossil *Williamsonia*.  
(b) Coniferophyta → Fossil *cordites*.
20. (d) Main plant body sporophyte of gymnosperm and angiosperm are made up of root, stem and leaves.
21. (b) *Ginkgo biloba*, a gymnosperm, is at present confined to the eastern part of China and Japan.
22. (a) *Gnetum*, *Ephedra* (Jointed fir) and *Welwitschia*. This is the only order in gymnosperms, where vessels are present in xylem.

### Pinus

3. (c) In *Pinus* annual ring consists of a zone of spring wood and autumn wood.
4. (d) Pollination in *Pinus* takes place when two prothallial cell, one generative cell and one tube cell are formed.
5. (d) Because pollen tube is present and dispersal of pollen grains by wind. So male gametes are not ciliate.
7. (c) Chilgoza is seed of *Pinus*.
10. (c) Male cones arise in place of dwarf shoots on long shoots and thus are equivalent to dwarf shoots
11. (b) Because endosperm is haploid ( $n$ ) and formed before fertilization and megaspore mother cell divides reductionally to form a linear tetrad of haploid megaspores and microspore (= pollengrain) is the first stage of the gametophyte ( $n$ ).
12. (a) Tracheidal cell present in xylem, vessels are absent.
13. (b) In *Pinus*, as the seed matures a thin layer of ovuliferous scale fuses with testa of the seed in the form of a wing, this help in the dispersal of seeds.
14. (d) In *Pinus* seed there are many cotyledons (3–18 cotyledons).
15. (b) Male prothallus (gametophyte) in *Pinus* is having two prothallial cells and one tube cell.
16. (c) Vascular strand is unbranched and covered by pericycle. It has generally two conjoint and collateral vascular bundles separated by T-shaped sclerenchyma.
17. (a) In the embryo of *Pinus* rosette tier (4 cells) above the suspensor tier and mediates between the suspensor tier and nutritive tier.
18. (b) Resin is collected from the stem/wood of *Pinus*. It is distilled to produce turpentine and rosin.
19. (d) Winged pollen grains produced in microsporangium which represents the male gametophyte of *Pinus*.
20. (b) In *Pinus* embryo with 3 to 18 cotyledons
21. (b) Brown membranous scale leaves (cataphylls) present on both long and dwarf shoots and serve to conserve water around the branches.
22. (c) Male gametophyte of *Pinus* is 4 celled (two prothallial cells, one generative cell and one tube cell).
23. (a) The wood of *Pinus* is pycnoxylic (more than one ring due to epimeral nature of cambium) and monoxyle (formed by the activity of single cambium).
25. (d) Because *Pinus* is gymnosperm plant.
26. (d) Dwarf shoot : In case of *Pinus*, actually in dwarf shoot the number of *Pinus* needles varies from one to six.
27. (b) Resin (Turpentine oil) : In *Pinus* roots, stem and needle, resin ducts are found having odorous oil known as resin. This resin is anticoagulant and do not allow to freeze water even upto  $-30^{\circ}\text{C}$  temperature in *Pinus* plants.
28. (c) The sporogenesis results in the formation of micro and megaspores representing the first gametophyte cells. They undergo gametogenesis so as to form the male and female gametophytes respectively.
29. (b) The 'endosperm' of *Pinus* is a haploid gametophytic tissue formed before fertilization.
30. (a) In gymnosperms and angiosperms gametophytes are dependent on sporophyte.
31. (b) As the seed matures, a thin layer of ovuliferous scale is fused with testa of seed in the form of wings.
32. (a) The seed of *Pinus* :  
(1) Parent  $2n$ , sporophyte represented by wing, testa, tegmen and perisperm (nucellus).  
(2) Female gametophyte ( $n$ ) represented by endosperm.  
(3) Future sporophyte ( $2n$ ) represented by embryo (Plumule, radicle, suspensor and cotyledons).
33. (a) Body cell divides into two daughter cells just before fertilization. These two cells are known as sperms.
34. (c) Seed of *Pinus* is endospermic, perispermic diploid ( $2n$ ). The wing of seed is thin, membranous diploid ( $2x$ ) and develops jointly from the basal upper surface (adaxial) of ovuliferous scale and outer layer of integument of the ovule.
35. (a) Monoecious
36. (b) In *Pinus* the pollination is anemophilous, (wind) i.e., pollen grains are carried to the ovule through wind.
38. (b) Female cone are morphologically equivalent to long shoot because female cone is 1.8 to 3 cm in 1<sup>st</sup> and 2<sup>nd</sup> year and 45 cm in length and 10 cm wide in third year.
39. (d) Siphonogamous fertilization : The fertilization in which a long pollen tube carry two male sperms near to egg cell is called as siphonogamous fertilization. This is only found in gymnosperms and angiosperms.
40. (c) Four embryos are formed from a single fertilized egg in cleavage polyembryony simple polyembryony i.e., When more than one embryos are developed as a result of fertilization of different archegonia.
41. (c) The microsporophylls of *Pinus* has 2 microsporangia on its abaxial surface.

### Cycas

1. (c) Diploxylic vascular bundles : In *cycas* leaflet, in central V.B two xylem and one phloem is found.
2. (a) The sperms of *cycas* are largest ( $300\mu$ ) in nature and visible to naked eye.
3. (c) Fern character in *cycas* is circinate venation in which younger leaf is coiled like a spring from apex downwards.

4. (a) *Anabaena*, *Nostoc* and bacteria are found in coralloid roots hence it helps in fixation absorption of nitrogen.
5. (d) A starch called sago is obtained from the pith of *cycas*, that so *cycas* is called sago palm.
6. (a) In the female plant, the apical meristem remains unaffected. Hence, the growth pattern is monopodial.
7. (a) The terminal sterile portion of the sporophyll is called apophysis.
8. (a) In one young seed only one embryo remains at maturity and others perish are called potential true polyembryony.
10. (c) Secondary growth is carried by successive rings of cambia (as many as 22 rings of vascular tissues are observed).
11. (c) Living fossil is that organism whose relatives have become extinct (Fossilised) and has a restricted distribution, therefore, threatened to become extinct.
14. (d) The sperm of *Cycas* is remarkably large in the entire plant kingdom. It is top shaped with 4-5 spiral coils of cilia at anterior half.
15. (c) Vessels is a characteristic feature of angiosperms.
16. (d) Size of largest ovule ~ 6 cm (length) 4 cm (dia), size of largest – sperm – 300 $\mu$ , size of largest egg – 0.5 mm in diameter
17. (b) *Cycas* is dioecious in which male and female sex organs are present in a single plant.
18. (d) Sago palm rich in starch.
19. (b) Monoxyle and Polyxyle : The wood is loose, soft, nonporous commercially useless, parenchymatous tissue more, vascular tissue less pith and cortex broad, medullary rays wide e.g., *cycas* wood.
20. (a) Stem pith of *cycas* having a number of mucilage canals.
21. (a) The pollination is anemophilous. The pollen grains of *cycas* are light in weight and easily blown away by wind.
22. (a) The megasporophylls is distinguishable in to a rachis part and a distal lamina in the upper part of the rachis are present to pairs of ovules, laterally.
25. (b) The 'endosperm' in *cycas* is a haploid gametophytic tissue formed before fertilization.
26. (d) The male gametes of *cycas* are largest (300 $\mu$ ) in nature, broad and naked at posterior end and spirally coiled in the anterior half with thousands of small cilia.
27. (d) *Anabaena* with coralloid roots is an example of symbiosis. It helps in  $N_2$  fixation.
29. (a) The pollen grains at this 3 celled stage fall directly on the pollination drop secreted by ovule as there is no stigma to receive pollen grains.
30. (b) Because sago is easily digestible with less starch (31%).
31. (a) Vessels are absent in gymnosperms.
32. (c) Bulbils (cresting adventitious buds), which are produced on the stem in the axil of scale leaves.
33. (a) Gynoecium is megasporophyll. Megasporophyll has stigma, style and ovary.
34. (d) In *Cycas* seeds are naked because it is not covered by ovary.
35. (d) Leaflet of *cycas* is diploxylic means 2 types of xylem – centripetal (exarch) and centrifugal (endarch).
36. (b) Microsporophyll bear sori of sporangia on the abaxial surface because the terminal portion is sterile.
38. (b) Motile sperms are found in both *Cycas* and *Adiantum*. Seeds, cambium are quite common in gymnosperms absent in pteridophytes.
39. (c) In young condition, young leaves show circinate ptyxis like fern leaves and are covered by ramenta.
40. (b) The zygote, which is the first sporophytic cell, undergoes free nuclear divisions.

### Angiosperms

4. (b) In monocots vascular bundles are conjoint collateral, closed scattered are called Atactostele.
5. (c) In dicots tap roots and in monocots adventitious roots is present.
6. (d) Phanerogams means seed bearing plants. Gymnosperms and angiosperms both possess seeds.
9. (d) In Angiosperm seeds are enclosed within a hollow ovary.
10. (b) Dicots are considered primitive over monocots.
11. (d) Secondary growth takes place in angiosperms because cambium are present (except monocots).
13. (b) The tip of the root of *Rafflesia* makes haustorial contact with the root of host and absorbs food from the host.
15. (a) Male gametophyte is highly reduced in angiosperm and is known as pollen grain. It is 2 or 3-celled.
16. (d) Megaspore Mother Cell (MMC) undergoes meiosis to form megaspore.

### Critical Thinking Questions

1. (b) *Adiantum* – Maiden Hair fern (because of shining, smooth and blackish hair like petioles).
2. (d) Seeds are formed after fertilization and consequent enlargement of the ovule. Two ovules or megasporangium are present on the adaxial side of ovuliferous scale. The ovuliferous scale and bracts constitute the megasporophyll.
6. (c) Because archegonia of *Pteris* secrete a chemical malic acid which attracts only sperms of *Pteris* chemotactically.
8. (d) *Equisetum* – Pteridophytes-Free living gametophyte – Prothallus.

**Riccia** – It is liverwort in which simplest sporophyte consists of capsule only while polytrichum is moss in which sporophyte consists of foot seta and capsule.

**Volvox** – oogamy is present.

**Slime moulds** – Spores bear cell wall.

9. (a) Such a sporangium arises from a single superficial initial. It divides periclinally into outer and inner components. While the inner cell forms the stalk, the outer gives rise to sporangium proper. In *Marattia alata*, the sporangia in a sorus may fuse to form a synanjo.
10. (a) Because endosperms of *Pinus* are always haploid and is formed before fertilization in ovules.
12. (d) The Microspores divides to form a 13 celled non-green, male gametophyte (one vegetative/prothallial cell + 8 jacket cell + 4 primary androgonial cells).
13. (d) Stigeoclonium shows heterotrichous habit which differentiated into prostrate and erect system.
15. (b) A – Mosses and lichen are pioneers on rocks  
B – Selaginella is heterosporous  
C – Coralloid roots of cycas has cyanobacteria – *Anabena cycadae*  
D and E are correct.
16. (d) The male cones are borne in a cluster on a branch of unlimited growth behind the apical bud, in the axil of a scale leaf. A cone consists of a central axis bearing 60-135 microsporophylls in spiral manner. It is therefore, comparable female flower of angiosperm.
17. (a) Some red algae deposit calcium carbonate on their surface. They are called coralline algae e.g., *Corallina*. They help to develop coral reefs alongwith corals.
18. (c) In ferns gametophytic generation is represented by heart shaped prothallus.
20. (b) Calyptra is a outermost protective covering of moss and liverwort
21. (d) *Zea* is monocot, *Cycas* have two and *Pinus* have many cotyledons in their embryo
23. (c) Heterospory, seed formation and fertilization are found in gymnosperm.
24. (d) The male gametes of *Riccia* and *Dryopteris* have flagella while male gametes of *Cycas* have cilia.
25. (d) The fertilization takes place after about a year of pollination.
26. (b) Sporophytes and gametophytes are morphologically differ in *Funaria*, *Selaginella* and *Cycas*.
27. (c) (A) Cyanophyceae – The blue-green colour is due to presence of a phycobilin pigment c-phyocyanin (also c-phycoerythrin).  
(B) Chlorophyceae – The green colour is due to presence of a chl. – a, chl. – b, xanthophylls and carotens.  
(C) Phaeophyceae – Brown colour is due to presence of pigment 'fucoxanthin'.  
(D) Rhodophyceae – Colour is red due to presence of a red pigment (r-phyocyanin) in the chromatophores.
28. (b) Endosperm in gymnosperms is formed before fertilization and is always haploid
29. (b) In *Pteris* antheridium is having (about 32) multiflagellated, coiled (2 – 3 coils) antherozoids or spermatozoids.
30. (c) Apospory is the formation of gametophyte directly from sporophyte without the meiotic formation of spores.
31. (d) At the base of ligule there is present a sheath of elongated cells called glossopodium (secretory). This ligule is secretory as well as protective. It secretes water/mucilage to keep growing point of stem and young leaves moist. It also protects young leaves.
34. (d)  
(1) Moss of Bryophytes bears protonemal and leafy stage.  
(2) Gymnosperm female gametophyte is not free living.  
(3) They are present in *Marchantia* of Bryophyte  
(4) Origin of seed habit started in *Selaginella*.

### Assertion and Reason

1. (b) Biennial plants live for two favourable seasons. During the first season, the plants grow in size and store food. In the second season, they bear flowers that form fruits.
2. (b) Bryophytes and tracheophytes possess an embryo stage. They are collectively called embryophyta. Bryophytes and tracheophytes are terrestrial plants. Bryophytes are nonvascular while tracheophytes possess vascular tissue.
3. (b) Stamens are specialized microsporophylls. Each stamen has a narrow stalk or filament and a knob-like broader tip called anther. Anther develops four microsporangia or pollen grains. Carpels are specialized megasporophylls. Each carpel has a swollen base named ovary. The interior of ovary contains one or more placentae for bearing ovules.
4. (a) On the basis of  
(i) Thallus like non-vascular plant body,  
(ii) Simple, unicellular non-jacketed sex organs and  
(iii) No embryo development after gametic union, the algae and fungi have long been grouped together in thallophyta. The algae and fungi are the result of parallel development and do not indicate any phylogenetic relationship
5. (a) The colour of the algal thallus which varies in different classes of algae is due to the presence of definite chemical compounds in their cells. These are called the pigments. Each pigment has its own characteristic colour. The particular colour that an alga has is due to the predominance of one pigment in a combination of several others. Each group of algae has its own particular combination of pigments and a characteristic colour which is not found in other algal groups.
6. (a) The red algae flourish and occur in abundance at great depths of sea where other plants do not occur in abundance. The sunlight as it penetrates water, portions of spectrum such as red, orange, yellow and green light rays which are of short wavelengths are filtered out. Only the blue and violet rays of great wavelength remain and penetrate to great depths. The green pigment chlorophyll cannot trap these light rays of great wavelength and the green plants are thus unable to carry on photosynthesis at these depth. On the other hand the red pigment r-phycoerythrin and a blue pigment γ-phyocyanin which are characteristic pigments of all the red algae, can utilize wavelengths of light (blue and violet rays) not absorbed by chlorophyll

7. (e) The carpogonium (female sex organ) in *Nemalion*, one of the simplest red alga, consists of a swollen basal part containing the female nucleus and an elongated terminal hair-like structure called the trichogyne. During fertilization the spermatium (male gamete) discharges its contents into the latter. The spermatium nucleus migrates downwards to fuse with the egg nucleus in the basal swollen part of the carpogonium. Soon after fertilization the trichogyne shrivels.
8. (a) In *Spirogyra*, the outermost portion of pectose changes into pectin. The latter dissolves in water to form the so called gelatinous sheath which is slimy. It envelopes the entire filament. This makes filament slippery in touch.
9. (c) The fusing gametes in the lower forms of algae are alike in size, structure and behaviour. They are indistinguishable as to sex. Such gametes are called the isogametes. Sexual reproduction which involves the fusion of isogametes is termed isogamous. It is a primitive type of sexual reproduction.
10. (a) Angiosperms is the highly evolved group of plant kingdom. It is adapted for terrestrial habitats. Swimming habit of sperms is completely lacking in angiosperm. The pollen grains reached to the stigma by an external agency and delivered the male nucleus in the ovule through pollen tube.
11. (b) Fertilized ovules ripen into seeds. The seeds are covered by fruits. A fruit is technically a ripened ovary. Gymnosperms contain ovules but they lack ovary, therefore, seeds are formed but fruits are not formed. Angiosperms contain both ovule and ovary and therefore, are seed bearing fruit forming plants.
12. (b) The chloroplasts of green algae contain one or more distinct, rounded, proteinaceous bodies called the pyrenoids. Pyrenoids diminish in size and ultimately disappear if the plant is under conditions of starvation. They reappear when the conditions become favourable.
13. (c) In green algae the eye spot is usually associated with the chloroplast. Eye-spot is considered as a photoreceptive organ.
14. (b) *Chlorella* could be utilised to keep the air in space vehicles pure and supply food in space stations and prolonged space flight trips. The space travellers could feed on *Chlorella* soup. It is nourishing but not appetizing food.
15. (b) In angiosperm, sporophylls are organised into flowers. Both microsporophylls and megasporophylls are specialised. A microsporophyll or stamen consists of a filament and an anther. A megasporophyll or carpel is rolled and partly sterilised to produce a stigma, style and ovary containing ovules.
16. (c) Many believed that *Chlorella* could serve as a potential source of food and energy because its photosynthetic efficiency can theoretically reach 8% comparable with other highly efficient crops nutrients. When dried, it has about 45% protein, 20% fat, 20% carbohydrate, 5% fibre and 10% minerals and vitamins.
17. (a) A life cycle characterized by a haploid thallus, and zygotic meiosis is called haplontic life cycle. It is also called as haplobiontic because only a single type of free living individual is involved in the life cycle. *Spirogyra* shows haplontic life cycle and therefore, it also shows zygotic nucleus.
18. (a) In some species of red algae called coralline algae, the cell walls become hardened with calcium carbonate. These algae hence important for the formation of coral reefs. Coral reefs are formed through the accumulation of calcareous exoskeletons of coral animals, calcareous red algae and molluscs. They form the foundation of reefs by secreting a calcium carbonate skeleton and provides protection for the coral polyps. Calcium carbonate is secreted continuously by the coral colony.
19. (a) Bryophytes are a group of non-vascular land plants. The sex organs in the bryophytes are multicellular and jacketed. The jacket of sterile cells around the sperms and eggs is an adaptation to a life on land. It protects the sex cells against the drying effects of air.
20. (e) Most of the bryophytes are land dwellers which inhabit damp, shaded and humid localities. A few of them live in or float on water. The bryophytes cannot carry on their reproductive activities without sufficient moisture. Presence of water is necessary.
21. (c) The bryophytes have evolved a life which comprises two phases-gametophyte and sporophytes. The gametophyte (haploid) is concerned with sexual reproduction and constitutes the most conspicuous, nutritionally independent phase in the life cycle. The sporophyte is dependent partly or wholly on the gametophyte for nutritional purpose.
22. (c) Thallophytes, i.e., algae and fungi completely lack the formation of embryo. In bryophytes, the zygote, on germination, does not produce the gametophyte plant. It undergoes segmentation to form an embryo. The embryo (diploid) by further segmentation and differentiation gives rise to sporophyte. The sporophyll obtains its nourishment directly from the parent gametophyte to which it is organically attached.
23. (c) The female sex organ of the bryophytes is a remarkable structure. It appears for the first time in the liverworts and mosses and continues in the pteridophytes. Archegonium is absent in thallophytes (algae and fungi). Sex organs in them are male gametes and female gametes.
24. (d) In bryophytes, the zygote, on germination, does not produce the gametophyte plant. It undergoes segmentation to form an embryo. But the embryo formation and its development to sporogonium and sporophyte are dependent on gametophyte plant as the sporophyte is dependent on the gametophyte for nutrition. They remain attached organically to the gametophytic plant. In algae, the zygote is independent and it does not form the sporophyte.
25. (b) Fragmentation leads to increase in the number of plants in a locality but it does not permit spread of the plant to an entirely new locality. Being small and sufficiently buoyant, gemmae are easily carried. When detached, they spread by water and wind currents to new habitats, where each grows into a new individual immediately.

26. (b) *Pinus* show alternation of generations. The sporophyte phase is of long duration and is represented by the huge pine tree, which bears the staminate and ovulate cones. Since meiotic divisions occur at the same time of the differentiation of the pollen grains and megaspores.
27. (e) In *Pinus*, the embryo is straight and consists of a short axis bearing a ring of about ten slender, yellow cotyledons at the end, away from the micropylar end. In *Pinus*, more than one embryo come from a single egg by the splitting of the product of a single fertilization, termed as cleavage polyembryony.
28. (b) The ovulate or female cones take three years to mature. The mature cones are hard, woody and very large in size. Many important changes take place in the female cone during the interval of about thirteen months between pollination and the actual act of fertilization.
29. (d) Female cones or ovulate cones are fewer in number and arise single or in a small cluster or two to four, each as a bud in the axial of a scale leaf towards the end of the new shoots of unlimited growth (long shoots) which do not bear the male cones.
30. (a) Each sperm of *Riccia* is a minute, slender curved structure. It is furnished with a pair of whiplash flagella at its anterior end. The sperms do not leave the antheridium until enough moisture is present to permit them to swim about. Several of the sperms may swim downward in the liquid in the neck.
31. (a) The sporogonium (capsule) of *Riccia* is the simplest among the liverworts. It lacks both the foot and the seta. There are no elater. Unlike other liverworts the embryo, sporogonium and spore mother cells in *Riccia* develop no chloroplasts. Thus no photosynthesis occurs there. The sporophyte remains totally dependent upon the gametophytic thallus.
32. (b) In young stems of *Funaria*, the cortical cells contain chloroplasts, hence, they are photosynthetic. The central cylinder forms the core of the stem. It consists of vertically elongated, thin-walled, narrow, compactly arranged cells without protoplasm. These thin walled, elongate, dead cells with nonlignified walls are commonly called the hydroids.
33. (c) *Pinus* is monoecious as it bears both types of cones on the same tree on separate branches. The male cone consists of a number of small spirally arranged microsporophylls. Each microsporophyll bears two microsporangia or pollen sacs as swelling on the lower surface of its horizontal position.
34. (c) The formation of small, underground resting, budlike structures called the tubers has also been reported in some mosses. Formerly these underground bud-like structures were called the bulbils. The tubers develop singly on stem, leaves and rhizoids as small, spherical storage organs containing starch. These serve as means of perennation and enable the plant to tide over periods unfavourable for vegetative growth.
35. (e) In *Funaria*, the gemmae develop on the stem and leaves of the gametophore at the onset of condition unfavourable of growth or during injury. These detached gemmae under conditions favourable for vegetative growth directly develop into new leafy gametophores.
36. (b) Morphologically *Funaria* looks dioecious, but it is monoecious.  
The antheridia (male sex organ) are formed at the summit of a relatively small, main leafy shoot which develops first. It is in fact the parent plant.  
The female branch arises later as a lateral outgrowth from the base of the parent male shoot. When the two kinds of the sex organs are borne in separate clusters on two distinct branches of the same plant the arrangement is called monoecious. *Funaria* is protandrous (male matures first). This ensures cross fertilization.
37. (e) In *Funaria*, the antheridia are not sunk in pits, but project from the surface of the receptacle and are aggregated to form a cluster. The leaves surrounding the antheridial cluster are known as the perigonial leaves. The antheridial cluster with the surrounding perigonial leaves is called the perigonium.
38. (b) The peristome teeth are present at the mouth of capsule. The teeth may be solid cellular tissue or composed only of the thickened portions of the cell walls of adjacent cells.  
When the teeth of peristome are solid structures composed of bundles of dead cells, it is termed *nematodontous* peristome are solid structures composed of bundles of dead cells, it is termed *nematodontous* peristome. It is found in *polytrichum*, *Pogonatum* and *Tetraphis*. If peristome composed of thin, membranous, transversely barred teeth, each tooth is made up of the thickened portions of the cell walls of adjacent cells. Such a peristome is called *orthodontous*.
39. (b) Within the hypodermis of *Pinus* leaf is the parenchymatous mesophyll. It is compact and shows no differentiation into palisade and spongy tissues. It consists of thin walled cells which contain numerous chloroplasts and abundant starch. The mesophyll thus functions as the chlorophyll bearing tissue which manufactures food for plants.
40. (a) Secondary growth takes place in the manner similar to dicotyledonous stem. The secondary wood shows well marked growth rings which are formed annually due to environmental fluctuations. Each annual ring possesses a zone of spring and an autumn wood. Spring wood is formed during season under availability of enough water and minerals. It possess large polygonal, thin walled and wide tracheids with large bordered pits. Autumn wood is formed during Autumn season. It possesses smaller, squishy, thick walled and narrow tracheids with small bordered pits. It is evident that the size of tracheids shows a marked variation with regard to amount of nature available in the respective season.

41. (a) Rubling and Tyler (1979) showed that air dried mosses can absorb metals. The accumulation of heavy metal cations in mosses enables them to be used as pollution indicators
42. (a) According to some Botanists, Mosses originated from algae. Protonema of mosses is similar to certain algae.
43. (c) In the sporangia of *Pteridium* are not grouped together in small separate sori, but the sorus is continuous along the under margin of the pinnules, often for considerable distances. This type of sorus is known as continuous linear sours (coenosorus).
44. (b) Indusium is an epidermal membranous outgrowth covering the sori in some ferns. The coenosorus is surrounded by two well formed indusial lips, between which lies the receptacle. The outer indusial lip is well-developed and is formed by the reflexed margin of the pinnule, which overlaps the coenosorus and its sporangia. This is commonly called the false indusium.
45. (b) In *Dryopteris*, young rhizome and leaves are covered with dry, brown, chaffy scales known as ramenta. In *Pteridium*, the rhizome and the leaves especially while young, are covered by a felt of simple hairs, and the scales are conspicuously absent.
46. (d) The scale leaves are present both on the long and dwarf branches. They fall off as the branches mature. The scale leaves on the dwarf shoots are called the cataphylls and possess a distinct midrib.
47. (d) In bryophytes, antheridia are well developed and often possess a stalk. In pteridophytes, antheridia are less developed and generally devoid of a stalk whereas pteridophytes has multiflagellate sperm formed from androcyte cell of antheridium. Bryophytes has biflagellate sperm.
48. (e) In fern, fertilization usually takes place if the prothalli are watered from above as they would be by rain in the ordinary course of nature. They possess flagella for swimming movement towards archegonia through water.

The discharged matter at the mouth of the opened archegonial neck probably contains some chemical substance, e.g. malic acid, which by positive chemotaxis attracts the free swimming antherozoids, which penetrate the neck and reach the deeply seated ovum.
49. (c) In the pteridophytes, the sporophyte gains physiological independence and develops into the dominant, typically photosynthetic phase of the life cycle. It is organized into stem, leaves and roots. For the first time in the sporophyte of the pteridophytes true roots develops. Psilophyta (a pteridophyte division) lack true roots.
50. (e) In gymnosperms, xylem lacks true vessels and wood fibres. It consists of tracheids that are arranged in uniform radial rows and xylem parenchyma only. The phloem contains sieve tubes and parenchyma cells. There are no companion cells.
51. (d) In eusporangiate type of development, large sporangia develop from a group of initials. In leptosporangiate type of development, small sporangia develop from a single initial, the former builds the entire sporangium, its contents and stalk and the latter takes no part in the process
52. (a) Leaf tips of *Adiantum caudatum*, develop adventitious buds for vegetative propagation. When leaf tip reaches the ground, it develops into new plant, therefore, it appears that the plant is walking.
53. (a) The gymnosperms have their ovules freely exposed before and after fertilization. They are not enclosed by any ovary wall. The seeds formed by them lack seed coat. Hence due to absence of every wall and seed coat their seeds are naked.
54. (b) Long branches of *Pinus* become gradually shorter towards the apex. Hence the pine tree has a conical or pyramidal appearance. Long branches bear short branches and older portion of long branches show the scars of fallen short branches.
55. (c) In *Cycas* there is no true and compact or properly organised female cone. Megasporophylls are loosely arranged and thus form a loose female strobilus. The growing point of the stem is unaffected by their development and continues its growth through the loose strobilus.
56. (c) All living species of *Cycas* are dioecious as the male and female structures occurs on separate plants. The microsporophylls are aggregated into large compact male strobili or cones. The megasporophylls are loosely arranged. They do not form a true cone.
57. (b) When the microspores reach maturity, the male cone elongates considerably and rapidly. The scales separate from one another so that sporangia are exposed. The sporangia lose water and with the loss of water from its cells the exothecium shrinks. The sporangia thus open by a slit on its outer face. The spores fall out. The liberated spores are dispersed by wind.



## Plant Kingdom

## Self Evaluation Test

- In ferns, xylem is
  - Exarch
  - Mesarch
  - Endarch
  - Polyarch
- Tracheophyte includes [Odisha JEE 2009]
  - Pteridophyte, gymnosperm and angiosperm
  - Bryophytes and spermatophytes
  - Only spermatophytes
  - Thalophytes and bryophytes
- Heterospory and seed habit are often exhibited by a plant possessing [CBSE PMT 1997; BVP 2009]
  - Bract
  - Spathe
  - Petiole
  - Ligule
- Match items in Column I with those in Column II
 

Column I	Column II
(A) Peritrichous flagellation	(J) <i>Ginkgo</i>
(B) Living fossil	(K) <i>Macrocystes</i>
(C) Rhizophore	(L) <i>Escherichia coli</i>
(D) Smallest flowering plant	(M) <i>Selaginella</i>
(E) Largest perennial alga	(N) <i>Wolffia</i>

 Select the correct answer from the following [CBSE PMT 2005]
  - A - L; B - J; C - M; D - N; E - K
  - A - K; B - J; C - L; D - M; E - N
  - A - N; B - L; C - K; D - N; E - J
  - A - J; B - K; C - N; D - L; E - K
- A female gametangium of bryophyte differs from that of fungus in possessing
  - Large neck
  - A venter
  - Jacket layer with sterile cells
  - A single egg cell
- Annulus of moss capsule separates [CMC Vellore 1993]
  - Operculum and columella
  - Theca and columella
  - Theca from operculum
  - Columella from apophysis
- The microspore of *Selaginella* may be as small as [MP PMT 2011]
  - 5 $\mu$
  - 15 $\mu$
  - 1.5 $\mu$
  - 5 $\mu$
- The major role in the dehiscence of a fern sporangium is played by its [AIIMS 1999]
  - Annulus
  - Indusium
  - Tapetum
  - Sorus
- Leaf gap in the vascular cylinder in ferns is
  - Air space
  - Parenchymatous zone
  - Collenchymatous zone
  - Area exclusively of phloem
- The female sex organ in *Riccia* and *Funaria* is [AIIMS 1992; BHU 1994]
  - Archegonium
  - Antheridium
  - Oospore
  - Paraphyses
- The sclerenchyma of the hypodermis in the *Pinus* needle helps in [AIIMS 1992]
  - Checking transpiration
  - Mechanical support
  - Photosynthesis
  - Increasing the absorptive surface of the cell
- Which one of the following characters is not shown by *Selaginella*
  - Circinate venation
  - Precocious germination
  - Microphyllous leaves
  - Protostele
- Match the following
 

A.	Red Algae	1.	Marchantia
B.	Liver wort	2.	<i>Pinus</i>
C.	Walking fern	3.	Polysiphonia
D.	Gymnosperm	4.	<i>Adiantum</i>

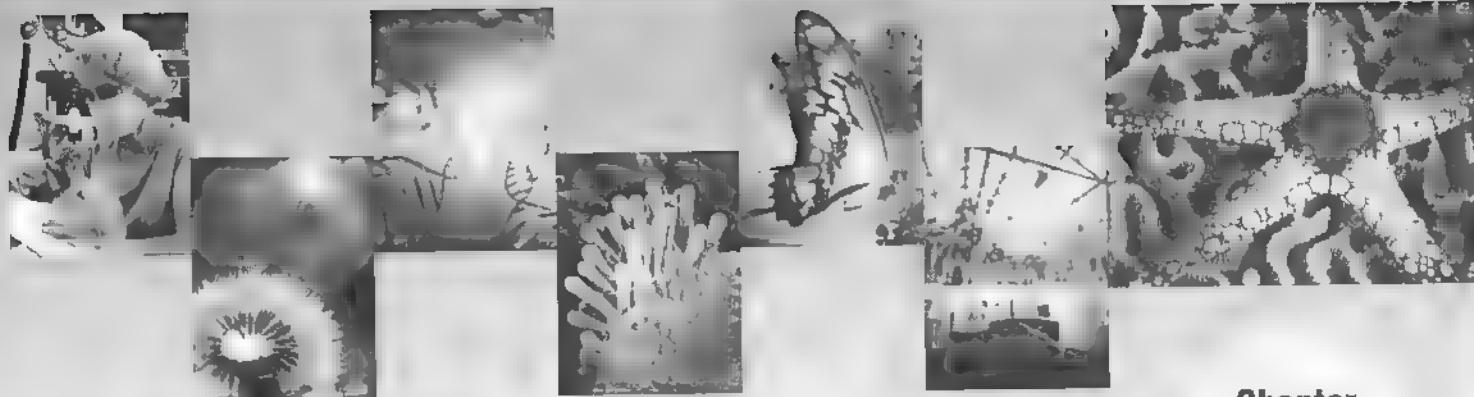
 [Kerala PMT 2006]
  - A - 1, B - 2, C - 4, D - 3
  - A - 2, B - 4, C - 3, D - 1
  - A - 2, B - 3, C - 1, D - 4
  - A - 3, B - 1, C - 4, D - 2
- Select the correct statement [Kerala PMT 2011]
  - Absorption of water by seeds and dry wood are examples of facilitated diffusion
  - The apoplast is the system of interconnected protoplasts
  - Pinus* seeds cannot germinate and establish without the presence of mycorrhizae
  - The translocation phloem is unidirectional whereas in the xylem it is bidirectional
- In bryophytes an operculum a cap like structure develops from [CPMT 1993]
  - Antheridium
  - Archegonium
  - Both (a) and (b)
  - None of these
- Number of flagella in male gametes of fern is [RPMT 1995]
  - Zero
  - One
  - Two
  - Infinite



17. Well developed archegonium with neck consisting of 4–6 rows of neck cells characterises [CBSE PMT 1995]  
 (a) Gymnosperms and flowering plants  
 (b) Bryophytes and pteridophytes  
 (c) Gymnosperms only  
 (d) Pteridophytes and gymnosperms
18. Meiosis (reduction division) in pteridophytes takes place at the time of [MP PMT 2003; AFMC 2004]  
 (a) Spore formation (b) Sexual organ formation  
 (c) Germination of spores (d) Gamete formation
19. Which organism lacks archegonium [MP PMT 2011]  
 (a) *Funaria* (b) *Pteris*  
 (c) *Cycas* (d) *Spirogyra*
20. *Laminaria* (kelp) and *Fucus* (rock weed) are the examples of [AFMC 2000; CBSE PMT 2001; BVP 2002; AMU (Med.) 2009; Kerala PMT 2012]  
 (a) Green algae  
 (b) Brown algae (Phaeophyceae)  
 (c) Red algae (Rhodophyceae)  
 (d) Golden brown algae
21. Rhizoids in *Funaria* arise from [CPMT 1998; MHCET 2003]  
 (a) Basal region (b) Ventral region  
 (c) Dorsal region (d) None of these
22. The walking fern is so named because [CBSE PMT 1998]  
 (a) Its spores are able to walk  
 (b) It is dispersed through the agency of walking animals  
 (c) It propagates vegetatively by its leaf tips  
 (d) It known how to walk by itself
1. (b) *Mesarch* : When in xylem, protoxylem and metaxylem are mixed then in ferns xylem becomes mesarch.
3. (d) Heterospory meant for the production of two different sizes of spores i.e., microspore and megaspore. It is found in *Selaginella*. In *Selaginella*, there is a small membranous ligule found at the basal portion of the leaf.
5. (c) A female gametangium of bryophyte differ from fungus multicellular sex organs surround by a single layered jacket of sterile cells
6. (c) Capsule has three parts – lower assimilatory apophysis, middle spore containing theca (with central sterile columella) and upper part having an operculum, peristome and annulus.
9. (b) The parenchymatous region left behind in the main stele after the departure of the leaf trace is called 'leaf gap'.
11. (b) Because sclerenchyma are thick wall cells.
12. (a) Circinate vernation is characteristic feature of division filicophyta (e.g., *Dryopteris*) while *Selaginella* include in division lycophyta.
15. (b) The upper region of capsule is slightly oblique having upper cap-like portion called operculum.
16. (d) Male gametes of fern is multiflagellated.
18. (a) In pteridophytes, spore mother cell undergo meiosis to form tetrahedral tetrads of spores.
20. (b) The large (giant) parenchymatous forms of brown algae are called kelps or sea weed or trees of seas or forest of sea. (e.g., *Macrocystis* 30–60m; *Nereocystis* 20–30m, *Laminaria* 2–12m). Both contain fucoxanthin, which is brown in colour. Due to which both are grouped under brown algae.
21. (a) On the lower portion of the leafy gametophore, there are present branched, multicellular rhizoids with oblique septa.
22. (c) *Adiantum caudatum* walking fern because its leaf tips when come in contact with soil, form new plants as adventitious buds develop at leaf tips. This helps in the spread of fern over a large soil surface and thus derives the name walking fern.

## AS Answers and Solutions

1	b	2	a	3	d	4	a	5	c
6	c	7	b	8	a	9	b	10	a
11	b	12	a	13	d	14	c	15	b
16	d	17	b	18	a	19	d	20	b
21	a	22	c						



## Chapter

# 1.7

## Animal Kingdom

### Important terms and Classification of animals

The kingdom animalia or animal kingdom is the kingdom of consumer organisms having ingestive type of nutrition. It is the largest kingdom, with 1.2 million members. It has numerous organisms having different type of form, structure, organisation, complexity and development.

#### General features of animals

The animals possess several general features which taken together, distinguish them from the members of other kingdom.

(1) Animals are multicellular eukaryotes and in most cases their body cells form tissues that become arranged as organs and organ systems.

(2) Animals have heterotrophic mode of nutrition. They get carbon and energy by ingesting other organism or by absorbing nutrients from them. Animals may be herbivores, carnivores, omnivores, parasites, suspension feeders or deposit feeders.

(3) Animals require oxygen for aerobic respiration.

(4) Animals are motile, possess active movement during some stage of their life cycle. Even the sessile sponges have free swimming larval stages.

(5) The animal body cells of nearly all species have diploid chromosome number.

(6) Animal cells lack a cell wall; this provides flexibility to their cells, the most striking characteristic of animals.

(7) Animals are able to make rapid responses to external stimuli as a result of the activity of nerve cells, muscle or contractile tissue or both.

(8) Animals can reproduce sexually. Although some exhibit remarkable diversity of reproductive behaviour, all are capable of sexual reproduction.

(9) Animal life cycle includes stages of embryonic development. Mitotic cell divisions (cleavage) transform the animal zygote into a multicellular embryo.

### Terms related to classification

(1) **Anaima** : Animals without red blood e.g., sponges, cnidaria, mollusca, arthropoda, echinodermata, etc.

(2) **Enaima** : Animals with red blood e.g., vertebrates.

(3) **Vivipara** : Animals which give birth to young ones are included in this subgroup e.g., man, dogs, cows, etc.

(4) **Ovipara** : Animals which lay eggs are included in this subgroup e.g., frogs, toads, lizards, snakes, birds, etc.

(5) **Anamniotes** : Vertebrates without embryonic membranes e.g., fishes, amphibians.

(6) **Anniotes** : Vertebrates with embryonic membranes (chorion, amnion, allantois, yolk sac) e.g., reptiles, birds, mammals.

(7) **Acraniata or Protochordata** : Chordates without cranium (brain box). It includes urochordata and cephalochordata.

(8) **Chordates** : Animals with notochord dorsal tubular nerve cord, paired pharyngeal gill slits. All urochordates, cephalochordates and vertebrates are called chordates.

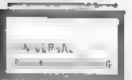
(9) **Craniata or Vertebrate** : Chordates with cranium. It includes cyclostomes, pisces, amphibians, reptiles, birds and mammals.

(10) **Nonchordates** : Animals without notochord (a rod like elastic structure which supports the body). Phylum Porifera to phylum Hemichordata are called nonchordates.

(11) **Invertebrates** : Animals without vertebral column (backbone). All the nonchordates, urochordates and cephalochordates are collectively called invertebrates.

(12) **Levels / Grades of organization** : Four levels of organization are found in multicellular animals.

(i) **Acellular or Molecular or Protoplasmic level** : It is present in protozoans.



(ii) **Cellular level** : The body consists of many cells which may be similar or show minor division of labour. Distinct tissues are not formed, e.g., sponges.

(iii) **Tissue level** : The body is multicellular. The cells form poorly defined tissues. The cells occur in two distinct layers or tissues of specialized cells e.g., coelenterates.

(iv) **Organ-system level** : The body is multicellular. The cells are organised into tissues, tissues into organs and organs into organ systems. Except sponges and coelenterates, all the animals of the kingdom animalia have organ-system level of organization.

(13) **Animal body plans** : It has three types of body plans :

(i) **Cell aggregate plan** : The body consists of a cluster or aggregation of cells which have rudimentary differentiation but are not organized into tissues or organs. It is found in sponges.

(ii) **Blind sac plan** : The body has a single cavity which functions as digestive tract and coelom both and have one opening to the outside. The single opening functions as both mouth for ingestion (intake of food) and anus for egestion (undigested waste is passed out) such a digestive tract is called incomplete. Animals having blind sac body plan show tissue grade body organisation. The cells are specialized, organised into tissues and show division of labour. It is found in coelenterates and flatworms.

(iii) **Tube-within-a-Tube plan** : The body has two tubes, one formed by the body wall and the second formed within it by the digestive tract. Digestive tract is a continuous tube-like structure that has two openings, a mouth for ingestion and anus for egestion. Such a digestive tract is called complete. In between two tubes is present coelom in which are present a number of organs. Food is digested and absorbed in the digestive tract. This type of body plan is found in Aschelminthes up to chordates.

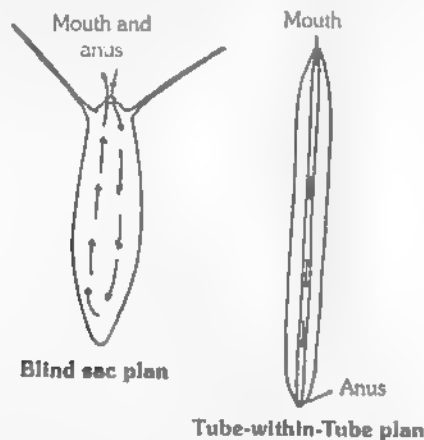


Fig : 1.7-1 Types of body plan

(14) **Animal symmetry** : Body symmetry is the similarity of parts in different regions and directions of the body. When the body is not divisible into equal halves by any plane it is called asymmetrical or asymmetric as found in *Amoeba* and some sponges. An animal is said to be symmetrical if its body is divisible into equal halves by one or more planes. Four types of symmetry found in animals are –

(i) **Spherical symmetry** : In this type of symmetry, any plane passing through the centre divides the body into equivalent or mirrored, halves. It is found in animals whose body resembles a sphere. e.g., Protozoans such as *Volvox*, *Heliozoa*, *Radiolaria*.

(ii) **Radial symmetry** : In this type of symmetry, a number of similar parts radiate out from a central axis. The body of the individual can be divided into equal halves by any plane passing through the centre from top to bottom. This type of symmetry is found in some sponges (*Sycon*), coelenterates (e.g., *Hydra*, jelly fish), echinoderms (e.g., star fish).

(iii) **Biradial symmetry** : In this type of symmetry, only two planes passing through the longitudinal axis. The body can be divided into two similar halves by one or two vertical planes only. This type of symmetry is found in sea walnuts (phylum ctenophora) and sea anemones (Anthozoa). The animals which show radial and biradial symmetry have oral and aboral sides. The oral side is that which has mouth, whereas the aboral side is one which is opposite to oral side.

(iv) **Bilateral symmetry** : In this type of symmetry, the body can be divided into two equal halves by a median longitudinal or sagittal plane only. The appearance of bilateral symmetry in animal evolution was a major advancement, because bilateral animals are much better fitted for directional (forward) movement than in radially symmetrical animals. This type of symmetry is found in many invertebrates and all vertebrates.

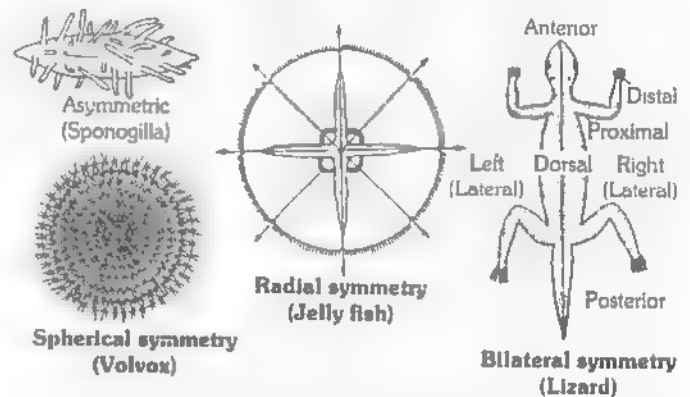


Fig : 1.7-2 Types of symmetry

(15) **Germ layers** : They are primary layers of cells which differentiate in the animal embryos at the gastrulation stage. The germ layers give rise to all the tissues/organs of the fully formed individual. The embryos of poriferans and coelenterates have two germ layers, the ectoderm and endoderm. These animals are called diploblastic. The embryos of all other animals (from phylum Platyhelminthes to phylum Chordata) have three layers – the ectoderm, mesoderm and endoderm. These animals are called triploblastic animals.

(16) **Segmentation** : Segmentation is a type of body form having a linear sequence of units of segments possessing a similar or modified structure. It occurs in three animal phyla—Annelida, Arthropoda and Chordata.

(17) **Metameric segmentation (True metamerism or True segmentation)** : It is a type of segmentation where external divisions correspond to internal divisions. The body is often divided both externally and internally into a number of segments (metameres) e.g., annelids. Segmentation is mostly external in arthropods and mainly internal in man and other chordates (vertebrae, body muscles, some blood vessels and nerves).

(18) **Pseudometamerism (False segmentation)** : It is found in tapeworms. In tapeworms, the proglottides (segments of tapeworms) are budded off from the neck, hence this segmentation is called pseudometamerism (pseudosegmentation). It differs from true segmentation of embryonic origin as found in annelids, arthropods and chordates.

(19) **Body cavity or Coelom** : A body cavity or coelom is a fluid-filled space between the gut and the outer body wall of an animal. It contains the major internal organs.

(i) **Acoelomates** : The animals which do not have coelom are called acoelomates e.g. sponges, coelenterates, ctenophorans and flat worms.

(ii) **Pseudocoelomates** : The animals which have body cavity, called pseudocoel (false coelom) derived from blastocoel of the embryo are called pseudocoelomates. Round worms (Nematelminthes) are pseudocoelomates.

(iii) **Eucoelomates (Coelomates)** : The animal which possess true coelom are called eucoelomates or coelomates. The true coelom is a body cavity which arises as a cavity in embryonic mesoderm. In this case, the mesoderm of the embryo provides a cellular lining, called coelomic epithelium or peritoneum, to the cavity. The coelom is filled with coelomic fluid secreted by the peritoneum. True coelom is of two types; schizocoelom or schizocoel and enterocoelom or enterocoel.

(a) **Schizocoelom**. It develops as a split in the mesoderm sheet. It is found in annelids, arthropods, molluscs.

(b) **Enterocoelom**. The mesoderm arises from the wall of the embryonic gut archenteron or enteron as hollow outgrowths which form this type of coelom. It occurs in echinoderms and chordates.

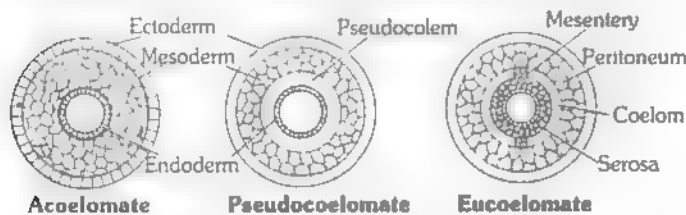
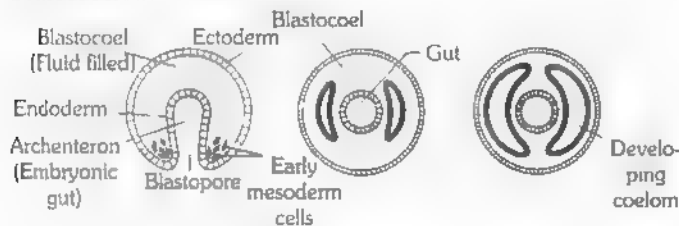


Fig : 1.7-3 Different types of coelom

#### Schizocoelous



#### Enterocoelous

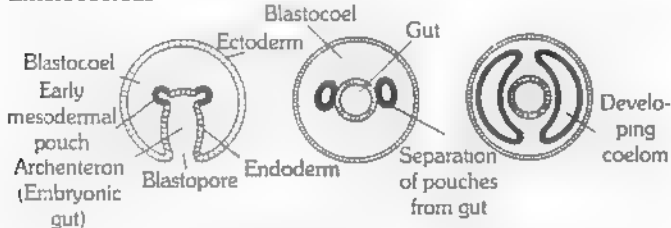


Fig : 1.7-4 Two different types of coelom formation

(iv) **Haemocoelomates** : The primary body cavity or blastocoel persists to some extent in many animals either enclosed within narrow blood vessels as in annelids or open as blood-containing space called a haemocoel and such animals are called haemocoelomates. Haemocoels occur in Mollusca and Arthropoda.

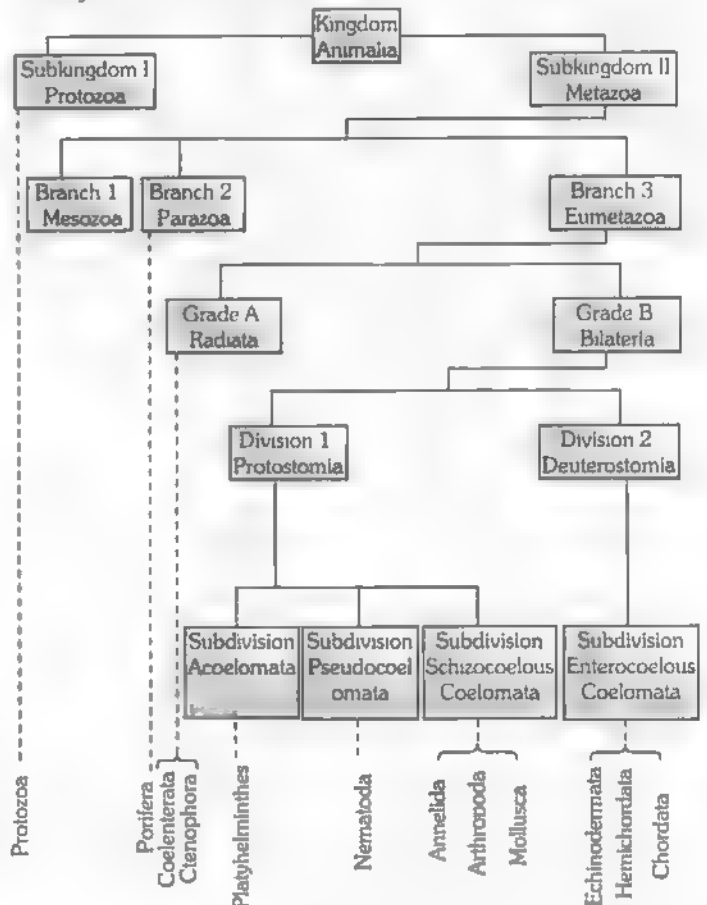
(20) **Protostomes and Deuterostomes** : The terms protostome and deuterostome denote the differences in the embryonic origin of the mouth.

In protostomes (first mouth) the mouth forms from the first opening of the embryo namely blastopore, the opening from outside into the archenteron, cleavage is determinate and spiral e.g. Platyhelminthes, Aschelminthes, Annelida, Arthropoda and Mollusca.

In deuterostomes (second mouth) the mouth never develops from the blastopore, although the blastopore may give rise to the anus cleavage which is indeterminate and radial. e.g. Echinodermata and chordata.

#### Outline classification of animal kingdom

The animal kingdom is subdivided into two sub-kingdoms, namely Protozoa and Metazoa.



**Subkingdom 1. Protozoa** : It includes microscopic, unicellular animals. It contains a single Phylum called protozoa. e.g. *Euglena*, *Amoeba*, *Paramecium* etc

**Subkingdom 2. Metazoa** : This subkingdom includes multicellular animals. e.g. Porifera to Chordata. The subkingdom Metazoa is divided into three branches, namely Mesozoa, Parazoa and Eumetazoa.

**Branch 1. Mesozoa :** It is intermediate between Protozoa and Metazoa. It includes endoparasitic animals, e.g. *Dicyema*, *Rhopalura* etc.

**Branch 2. Parazoa :** It includes sponges.

**Branch 3. Eumetazoa :** It includes true multicellular organisms. They have tissue organ and organ system grade of organization. e.g. Coelenterata to Chordata. Eumetazoa is further divided into two grades, namely Radiata and Bilateria.

**Grade A. Radiata :** It includes radially symmetrical animals. e.g. Coelenterata

**Grade B. Bilateria :** It includes bilaterally symmetrical animals. e.g. Platyhelminthes to Chordata. The grade Bilateria is further divided into two divisions namely protostomia and deuterostomia.

**Division 1. Protostomia :** In this group of animals, the blastopore develops into the mouth. It is further divided into 3 subdivision.

**Subdivision 1. Acoelomata :** In this group of animals, a coelom (Cavity lying between the gut and the body wall) is absent. e.g. Platyhelminthes

**Subdivision 2. Pseudocoelomata :** In this group of animals, a false coelom (cavity not lined with coelomic epithelium) is present. e.g. Aschelminthes or Nematoda

**Subdivision 3. Schizocoelous Coelomata :** In this group, a true coelom is present. e.g. Annelida to chordata.

**Division 2. Deuterostomia :** In this group of animals, the blastopore develops into the anus. It consist of one subdivision.

**Subdivision Enterocoelous coelomata :** Coelom is enterocoel which originates as pouches of embryonic gut (archenteron)

**Characters of Non Chordata (Invertebrates) :** The animals which lack vertebral column are called invertebrates. e.g. *Amoeba*, sponges, *Hydra*, worms, insects, etc., Invertebrates are characterised by the following salient features –

- (1) The vertebral column is absent.
- (2) The nerve cord is solid in nature
- (3) The nerve cord is present on the ventral side and never on the dorsal side
- (4) When alimentary canal is present, it lies dorsal to the nerve cord
- (5) Invertebrates may be acoelomate or pseudocoelomate or true coelomate
- (6) They have either asymmetry or radial symmetry or bilateral symmetry.

(7) The circulatory system is open type or closed type.

(8) They exhibit all possible types of reproduction.

The invertebrates are grouped into about 30 phyla. These phyla are of two types, namely minor phyla and major phyla.

**Minor phyla :** (1) Mesozoa (2) Nemertinea (3) Endoprocta (4) Acanthocephala (5) Rotifera (6) Gastrotricha (7) Kinorhyncha (8) Nematomorpha (9) Ectoprocta (10) Brachiopods (11) Phoronida (12) Chaetognatha (13) Priapulida (14) Sipunculida (15) Echiuroidea (16) Pogonophora etc.

**Table : 1.7-1 Major phyla : It include following phylum**

Phylum	Some representatives	Existing species
Porifera	Sponges	5,000
Cnidaria	Hydrozoans, jellyfishes, corals, sea anemones	9,000
Ctenophora	Venus's girdle	100
Platyhelminthes	Turbellarians, flukes, tapeworm	13,000
Nemathelminthes	Pinworms, hookworms	15,000
Annelida	Polychaetes, earthworms, leeches	9,000
Mollusca	Snails, slugs, clams, squids, octopuses	60,000
Arthropoda	Crustaceans, spiders, insects	900,000
Echinodermata	Sea, stars, sea urchins	6,000
Chordata	Protochordates (nonvertebrates)	2,100
	Fishes	25,600
	Amphibians	3,000
	Reptiles	6,000
	Birds	9,000
	Mammals	4,000

**Phylum Porifera : The sponges (pore bearing animals)**

(Gk. *Porus* = Pore; *ferre* = To bear)

**Brief History :** Robert Grant (1825) finally proved that sponges are animals, and coined the name 'Porifera' for these. Schulze (1878), Butschli (1884), Sollas (1884) and Delage (1898) separated sponges from other metazoans on the basis of embryological studies, and suggested a separate group, "Parazoa" for these.

#### General Characters

(1) All the sponges are aquatic, sedentary, asymmetrical or radially symmetrical. These are the first multicellular organisms and have cellular grade of organization.

(2) They are diploblastic. Ectoderm is formed by pinacocyte and endoderm is formed by choanocyte. Both layers are called pinachoderm and choanoderm. A gelatinous noncellular mesenchyme is present in between them.

Choanocytes (flagellated collar cells) are present only in sponges

(3) Mesenchyme contains free amoebocytes and skeletal elements.

(4) Different types of amoebocytes are :

Archaeocytes : undifferentiated totipotent cells.

Chromocytes : with pigment granules.

Thesocytes : with reserve food granules.

Myocytes : highly contractile, spindle-shaped cells.

Trophocytes : supply nutrients to developing cells (nurse cells)

Gland cells : secrete slimy substance

Sex cells : develop from archaeocytes only during breeding season.

(5) The body is perforated by numerous minute pores called ostia.

(6) The ostia open into a large cavity called spongocoel or paragastric cavity.

(7) The spongocoel opens to the outside by a large opening called osculum.

(8) Sponges have a canal system and they need a continuous current of water flowing through their bodies for respiration, excretion, nutrition and reproduction.

(9) Different types of canal system in sponges are asconoid, syconoid and leuconoid.

(10) The simplest type of canal system in porifera is asconoid type

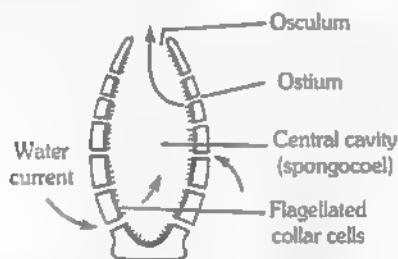


Fig : 1.7-5 Asconoid Type of canal system

(11) The course taken by the water current may be shown as under –

Ingressing water  $\xrightarrow{\text{Ostia}}$  Spongocoel  $\xrightarrow{\text{Osculum}}$  To outside

(12) The sponges possess an endoskeleton in the form of calcareous spicules, siliceous spicules and spongin fibres.

(13) Excretion and respiration occur by diffusion.

(14) They have greater power of regeneration due to totipotent archaeocytes.

(15) Digestion in sponges is intracellular like protozoans. Digestion takes place in the choanocytes.

(16) All sponges are hermaphrodite, reproduction takes place by asexual or sexual methods.

(17) Gemmules are internal buds containing archaeocytes, mostly found in fresh water sponges, concerned with asexual reproduction.

(18) Development is indirect or direct. The common larval forms are parenchymula (*Leucosolenia* and *Clathrina*), amphiblastula (*Sycon*), etc

**Classification of porifera :** On the basis of types of endoskeleton, phylum porifera is divisible into three classes

#### Class 1. Calcareous or Calcispongiae

(1) Skeleton is formed of Calcareous spicules

(2) Radially symmetrical.

(3) Choanocyte cells are large and conspicuous.

(4) Canal system asconoid (ascon) or syconoid (sycon) type.

(5) These are also known as limy sponges.

Examples : *Clathrina*, *Leucosolenia*, *Sycon*, *Grantia*, etc.,

□ *Leucosolenia* is a smallest sponge with asconoid type of canal system.

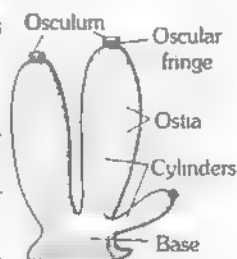


Fig : 1.7-6 Sycon

#### Class 2. Hexactinellida Or Hyalospongiae

(1) Skeleton is formed of six rayed triaxon, siliceous spicules,

(2) Canal system is branched or unbranched.

(3) Radially symmetrical.

(4) These are also known as glass sponges

Examples : *Pheronema*, *Hyalonema*, *Euplectella*, etc.,

□ *Euplectella* is the sponge which is given as a Gift in Japan and known as "venus flower basket". It show commensalism with shrimps of the genus *spongicola*, 'life upto death'.

#### Class 3. Demospongia

(1) Skeleton either absent or present. When present it is either formed of spongin fibres or combination of spongin fibres and siliceous spicules.

(2) The siliceous spicules when present are never six rayed.

(3) The canal system is complicated Rhagon type or leuconoid type.

(4) Rhagon larva is formed.

(5) These sponges are of great economic importance.

Examples : *Cliona*, *Spongilla*, *Chalina*, *Euspongia*, *Hippospongia*, *Oscarella*, etc.,

□ *Spongilla* is a fresh water sponge.

□ *Cliona* is harmful to oyster industry.

□ *Spheclospongia* is the largest sponge.

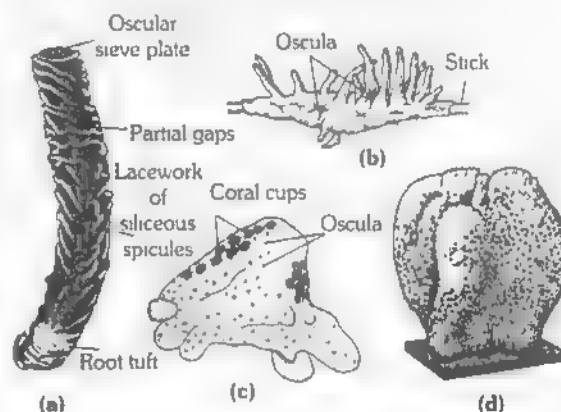


Fig : 1.7-7 Some economically important – sponges

(a) *Euplectella* (b) *Spongilla*  
(c) *Cliona* (d) *Euspongia*

Table : 1.7-2 Common Names

<i>Scypha</i> (= <i>Sycon</i> )	–	Um sponge, Crown sponge
<i>Euplectella</i>	–	Venus' flower-basket
<i>Phyllospongia</i>	–	Leaf sponge
<i>Pheronema</i>	–	Bowl sponge
<i>Hyalonema</i>	–	Glass-rope sponge
<i>Cliona</i>	–	Boring sponge
<i>Chalina</i>	–	Mermaids gloves (Dead man's fingers)
<i>Spongilla</i>	–	Freshwater sponge
<i>Euspongia</i>	–	Bath sponge, Horse sponge
<i>Poterion</i>	–	Neptune's goblet
<i>Hippospongia</i>	–	Horse sponge
<i>Hircinia</i>	–	Horny sponge

## Phylum-Cnidaria (Coelenterata)

(Gk. *knife* = nettle or stinging cell)

**Brief History :** Peyssonel (1723) and Trembley (1744) proved these to be animals. Hence, Linnaeus (1758), Cuvier (1796) and Lamarck (1801) included these under 'Zoophyta', together with sponges. Leuckart (1847) included sponges and cnidarians under his phylum Coelenterata. Finally, Hatschek (1888) divided "Coelenterata" into three phyla-Spongiaria (= Porifera), Cnidaria and Ctenophora.

### General characters

- (1) Coelenterates are radially symmetrical animals with tissue grade of body organization.
- (2) All the members of this phylum are aquatic, mostly marine.
- (3) They are solitary or colonial, sedentary or free swimming.
- (4) The body wall is diploblastic. It is made up of two layers of cells namely the ectoderm and the endoderm with a non-cellular layer called mesogloea in between.
- (5) Cnidarians exhibit dimorphism with polypoid and medusoid stage (Metagenesis or alternation of generation).
- (6) Asexual phase is generally polyp and sexual phase is medusa.
- (7) Coelom is absent; Hence coelenterates are acoelomate animals.
- (8) A gastrovascular cavity or coelenteron is present. It can be compared to the gut of higher animals
- (9) Mouth is present but anus is absent (blind-sac body plan). Mouth is surrounded by tentacles
- (10) The most characteristic feature of coelenterates is the presence of nematocysts or stinging cells.
- (11) Digestion is extracellular as well as intracellular.
- (12) Respiratory, excretory and circulatory system are absent. Oxygen is carried to various tissues through general body surface by diffusion.
- (13) Primitive nervous system with synaptic or non-synaptic nerve net but no brain.
- (14) Sense organs are statocysts (tentaculocysts), ocelli and olfactory pits.
- (15) Reproduction both asexual and sexual.
- (16) Development is indirect as there are one or two larval forms, Planula (*Obelia*) and Ephyra (*Aurelia*).

**Classification of coelenterata :** On the basis of the dominance of medusoid or polypoid phase in the life cycle, phylum coelenterata is divided into three classes –

### Class 1. Hydrozoa (Gr. hydros, water, zoios, animal)

- (1) Hydrozoa are solitary and fresh water or mostly colonial and marine, sessile and free-swimming forms.
- (2) They exhibit tetramerous or polymerous radial symmetry.
- (3) Body wall consists of an outer ectoderm and an inner endoderm separated by a non-cellular gelatinous mesogloea.

(4) Gastrovascular cavity is without stomodaeum, septa or nematocysts bearing gastric filament.

(5) Skeleton or horny structure is horny perisarc in some forms, while coenosarc secretes a skeleton of calcium carbonate forming massive stony structure or coral in other forms

(6) They exhibit polymorphism. There are two main types of zooids, the polyp and medusa. Medusa is provided with true muscular velum.

(7) Many hydrozoa exhibit alternation of generation.

(8) Reproductive products of sex cells are usually ectodermal in origin and discharged externally

(9) Cleavage is holoblastic, embryo ciliated planula.

(10) Both polypoid and medusoid stages are present.

**Examples :** *Hydra*, *Tubularia*, *Bougainvillea*, *Hydractinia*, *Eudendrium*, *Pennaria*, *Obelia*, *Sertularia*, *Plumularia*, *Companularia*, *Millepora*, *Stylaster*, *Geryonia*, *Physalia*, *Porpita*, *Velella*, *Pericarpa*, *Periphylla*, *Cynaea*, *Rhizostoma* or *Pilema* *Cassiopela*, etc.,

□ *Obelia* is trimorphic and marine colony.

□ Hydranth of *Obelia* bears twenty four (24) tentacles while medusa bears sixteen (16) tentacles in addition to tentaculocysts.

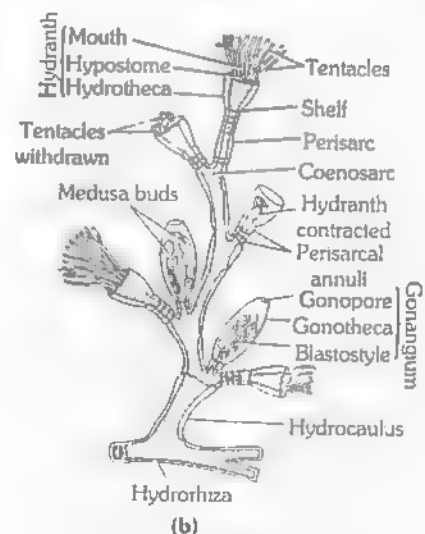
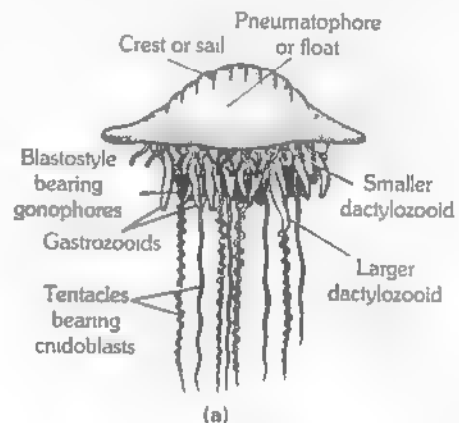


Fig : 1.7-8 (a) *Physalia* (b) *Obelia*

**Class 2. Scyphozoa** (Gr. skyphos, cup, zoios, animal)

- (1) Scyphozoa include large jellyfishes or true medusae.
- (2) They are exclusively marine.
- (3) Medusae are large, bell or umbrella-shaped and without true velum. They are free swimming or attached by an aboral stalk.
- (4) Marginal sense organs are tentaculocysts
- (5) Polypoid generation is absent or represented by small polyp, the scyphistoma which gives rise to medusae by strobilization or transverse fission.
- (6) Gastrovascular system is without stomodaeum, with gastric filaments and it may or may not be divided into four inter-radial pockets by septa.
- (7) Mesogloea is usually cellular
- (8) Gonads are endodermal and the sex cells are discharged into the stomach.

Examples : *Lucernaria*, *Haliclysus*, *Aurelia*, *Rhizostoma*, *Charybdea*, *Periphyllia*, *Chrysaora*.

□ *Rhizostoma* is a polystomous scyphozoan with many mouth bearing structures called scapules.

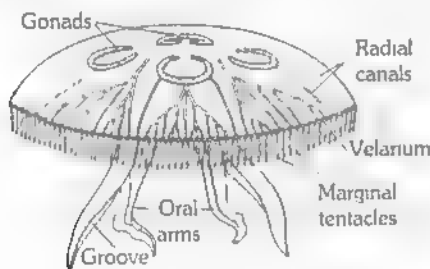


Fig : 1.7-9 *Aurelia*

**Class 3. Anthozoa (Actinozoa)**

- (1) These are solitary or colonial exclusively marine forms.
- (2) They are exclusively polypoid. Medusoid stage is altogether absent.
- (3) Body is cylindrical with hexamerous, octomerous or polymerous biradial or radiobilateral symmetry.
- (4) The oral end of the body is expanded radially into an oral disc bearing hollow tentacles surrounding the mouth in the centre.
- (5) The stomodaeum is often provided with one or more ciliated grooves, the siphonoglyphs.
- (6) Gastrovascular cavity is divided into compartments by complete or incomplete septa or mesenteries.
- (7) Mesenteries bear nematocysts at their free edges.
- (8) Mesogloea contains fibrous connective tissue and amoeboid cells.
- (9) They are exclusively marine, many forms corals.

**Subclass 1. Alcyonaria (Octocorallia)**

- (1) These are colonial manne forms.

(2) Polyps are long or short cylinders terminating orally into a flat circular oral disc having the oval or elongated mouth in the centre

- (3) Polyps always bear eight pinnate, hollow tentacles.
- (4) Eight complete mesenteries are present.
- (5) Single ventral siphonoglyph is present
- (6) Endoskeleton is the product of mesogloea cells comprised of calcareous spicules either calcareous or horny in nature.
- (7) Polyps are dimorphic in some forms.

Examples : *Tubipora*, *Clavularia*, *Alcyonulum*, *Xenia*, *Heliopora*, *Gorgonia*, *Corallium*, *Testudo*, etc.,

□ Corals form rocks in the sea, called the coral reefs. The largest coral reef is the great barrier reef which is 1200 miles long and surrounds Australia complete.

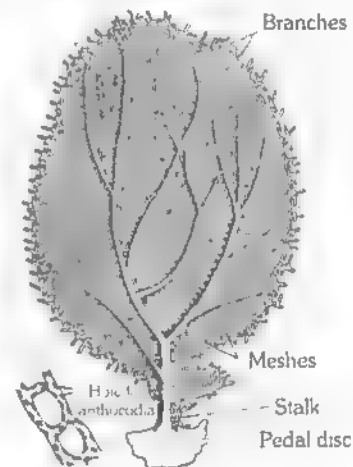


Fig : 1.7-10 *Gorgonia*

**Subclass 2. Zoantharia (Hexacorallia)**

- (1) These are solitary or colonial marine forms.
- (2) Tentacles simple, rarely branched, hollow cone shaped, numerous arranged in the multiple of five and six but never eight.
- (3) Mesenteries are numerous ananged in the multiple of five or six, may be complete or incomplete.
- (4) Two siphonoglyphs are commonly present.
- (5) Endoskeleton when present is calcareous, derived from ectoderm.
- (6) Polyps are usually monomorphic.

Examples : *Actinia*, *Metridium*, *Adamsia*, *Edwardia*, *Astraea*, *Fungia*, *Zoanthus*, *Antipathes*, *Aeropora* or *Madrepora*, etc.

□ *Metridium* shows commensalism with *Eupagurus*.

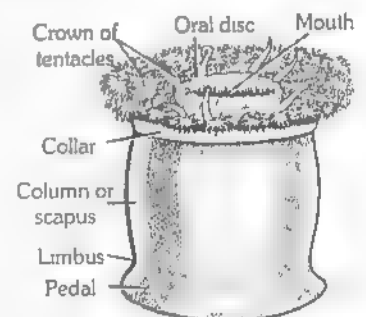


Fig : 1.7-11 *Metridium*



## Some representative animals

**Hydra**

(1) *Hydra* belongs to class Hydrozoa of phylum coelenterata

(2) Trembly (1744), a Swiss biologist discovered *Hydra*.

Linnaeus (1758) gave the name *Hydra*, a Greek word, means 'Water serpent' based on its ability to regenerate its lost parts.

(3) *Hydra* is a solitary polyp found in freshwater (stagnant). Among coelenterates *Hydra* is one of the smallest polyps.

(4) It is colourless carnivorous coelenterate having radial symmetry.

(5) *Hydra* is diploblastic and has tissue grade of organization with division of labour on morphological basis.

(6) *Chlorohydra viridissima* is called green hydra. It is green because of symbiotic association with a unicellular green algae *Chlorella vulgaris*. Algae live in the muscunonutritive cells of *Hydra*.

(7) *Hydra* has a cylindrical body with 6-10 hollow tentacles. It helps in locomotion and food capture, so analogous (correspond functionally) to pseudopodia of *Amoeba*.

(8) Mouth is situated on a manubrium or hypostome. It is most sensitive in the body. *Hydra* has no anus.

(9) The body wall of *Hydra* consists of ectoderm and endoderm, in between a thin, delicate, transparent and non-cellular mesogloea.

(10) Ectoderm consists of epithello-muscular cells, sensory cells, nerve cells, interstitial cells (totipotent) and stinging cells or cnidocytes having nematocysts.

(11) Inner gastrodermis has nutritive muscular cells, gland cells, nerve cells, sensory and interstitial cells. Nutritive muscular cells bear both flagella and pseudopodia.

(12) The contraction of muscle fibres in endothelio-muscular cells or nutritive muscle cells reduces the diameter of the body and works like circular muscles.

(13) Mesogloea is thin and acellular consisting of a proteinaceous matrix and it can be crossed by interstitial cells. It is neither cellular nor fibrous.

(14) Cnidoblasts or nematocysts are derived from interstitial cells of epidermis.

(15) Body cavity of *Hydra* is called coelenteron or gastrovascular cavity. Coelenteron serves the double purpose of digestion and circulation.

(16) Nematocysts are found only in epidermis mainly on tentacles. Nematocysts are also known as "independent effectors".

(17) *Hydra* paralyzes its prey by nematocyst. If all nematocysts of a *Hydra* are removed it would affect its capacity to capture prey.

(18) Nematocyst plays an important role in locomotion, food capture both offence and defence

(19) *Hydra* has four types of nematocysts : Penetrants or stenoteles (largest), valvents (smallest), stereoline glutinants (small, atrichous) and streptoline glutinants (large holotrichous)

(20) Digestion in *Hydra* is first extracellular (in gastrovascular cavity) and then intracellular (in endoderm cells).

(21) *Hydra* has no specialized cells for respiration, it respire by means of general body surface.

(22) Nitrogenous excretory product in *Hydra* is ammonia and it is removed through general body surface.

(23) *Hydra* possesses a very primitive nervous system consisting of a synaptic network of bipolar and multipolar nerve cells, but brain is absent.

(24) *Hydra* is monoecious or dioecious. Most species are dioecious or unisexual. Bisexual species of *Hydra* are protandrous, so avoid self-fertilization.

(25) *Hydra* reproduces asexually by exogenous budding, a type of vegetative propagation, and sexually by formation of gametes. *Hydra* reproduces by budding when plenty of food is available.

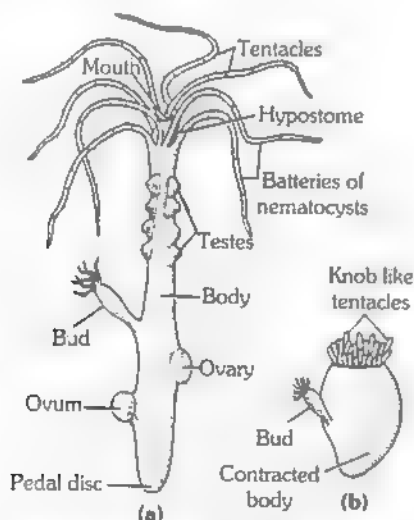


Fig : 1.7-12 *Hydra* (a) Expanded body with bud and gonads (b) Contracted body bearing bud

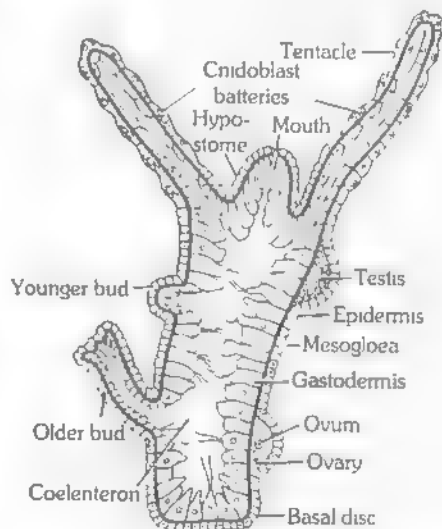


Fig : 1.7-13 Longitudinal section of entire animal

(26) *Hydra* normally possesses a single ovary (in aboral region) and many testes (in oral region).

(27) Fertilization occurs externally on the body by the entry of sperm into ovum.

(28) The developing embryo in *Hydra* drops down from the body of parent after the formation of gastrula.

(29) In the development of *Hydra* there is no moulting or ecdysis.

(30) No free larval stage (only a planula like stage) occurs in *Hydra*.

(31) *Hydra* has great regeneration capacities. A piece of *Hydra* will regenerate into a full *Hydra* if it contains a part of epidermis and gastrodermis and size is not less than 1/6 mm in diameter.

**Table : 1.7-3 Common Names**

<i>Obelia</i>	–	Sea fur
<i>Millipora</i>	–	Stinging coral
<i>Physalia</i>	–	Portuguese man-of-war
<i>Velella</i>	–	Little sail, Purple sail
<i>Chitrosalmus</i>	–	Sea wasp
<i>Aurelia</i>	–	Jellyfish
<i>Metridium</i>	–	Sea anemone
<i>Adamsia</i>	–	Sea anemone
<i>Pennatula</i>	–	Sea pen
<i>Corallium</i>	–	Precious red coral
<i>Meandrina</i>	–	Brain coral
<i>Tubipora</i>	–	Organ pipe coral
<i>Heliopora</i>	–	Blue coral
<i>Astraea</i>	–	Stony coral
<i>Virgularia</i>	–	Walking stick
<i>Fungia</i>	–	Mushroom coral
<i>Alcyonium</i>	–	Dead man's finger

### Phylum-Ctenophora or Acnidaria- The comb Jellies

(Gk. *kteis* = comb; *pherein* = To bear)

**Brief History :** The ctenophores as a distinct group were first recognized by Eschscholtz (1829). Hatschek (1889) placed it under a separate phylum called ctenophora.

#### General characters

- (1) All the ctenophores are marine.
- (2) They are solitary and pelagic.
- (3) They are transparent.
- (4) They have tissue-grade of organization.
- (5) They have biradial symmetry.
- (6) They are acoelomate animals.
- (7) They are unsegmented.
- (8) Their body-wall is diploblastic.
- (9) The mesogloea contains cells.

(10) Nematocysts are absent.

(11) Special adhesive cells called colloblasts are present in all ctenophores.

(12) The gastrovascular system is well developed.

(13) Two anal openings are present.

(14) Skeletal system is absent.

(15) Excretion and respiration are carried out by diffusion.

(16) The nervous system is in the form of nerve net.

(17) An aboral sense organ is present in the form of statocyst.

(18) Cilia are used for locomotion.

(19) They are hermaphrodites.

(20) Development is indirect. It includes a cydippid larva.

#### Classification of Ctenophora

##### Class 1. Tentaculata

(1) The body is simple, rounded or oval or ribbon-like.

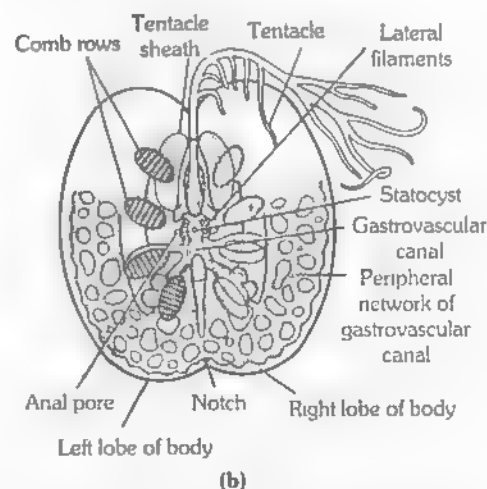
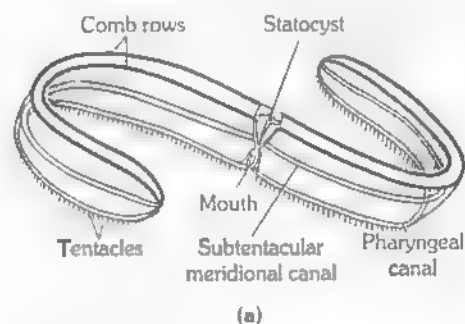
(2) Two long aboral tentacles are present.

(3) Mouth is narrow and pharynx is small.

**Examples :** *Pleurobrachia*, *Hormiphora*, *Mertensia*, *Mnemiopsis*, *Bolinopsis*, *Velamen*, *Cestum*, *Ctenoplana*, *Coeloplana*, etc.

□ *Cestum* is commonly called "venus's girdle".

□ *Ctenoplana* shows commensalism with *Alcyonea*.



**Fig : 1.7-14 (a) *Velamen* (b) *Ctenoplana***

**Class 2. Nuda**

- (1) Body is large thimble-shaped or conical.
- (2) Tentacles are absent.
- (3) Mouth is wide and pharynx is large.
- (4) The meridional vessels are produced into a complex system of anastomosing branches.

Example : *Beroe*

- *Beroe* is commonly called "Swimming eye of cat".

**Phylum Platyhelminthes : The flat worms**

(Gk. *platys* = broad or flat; *helmin* = worm)

**Brief History :** Aristotle mentioned tapeworms, but scientific studies of flatworms began only in the 18th century. It was Gegenbaur (1859) who placed these in a separate group and suggested the present name of the phylum.

**General Characters**

- (1) They are dorso-ventrally flattened like a leaf.
- (2) They show organ grade of organization.
- (3) They are acoelomate animals. The cavity in platyhelminthes is filled with mesenchyme or parenchyma.
- (4) They are triploblastic animals. The cells of the body wall are arranged in three layers. They are the ectoderm, the mesoderm and the endoderm.
- (5) They are bilaterally symmetrical animals. The body of the animal can be divided into two equal similar halves through only one plane. Animals with this symmetry have definite polarity of anterior and posterior ends.
- (6) Some members have segmented body. The segmentation in platyhelminthes is called pseudometamerism.
- (7) Many of the parenchyma cells give rise to muscle fibres. The muscle fibres are arranged in circular, longitudinal and vertical layers.
- (8) The digestive system is completely absent from Cestoda and Acoela. The alimentary canal is branched in Turbellarians. The anus is absent from them.
- (9) The respiratory organs are absent. In parasites respiration is anaerobic.
- (10) There is no circulatory system.
- (11) The excretory system is formed of protonephridia (flame cells or solenocytes).
- (12) Anus is absent like coelenterates, with blind sac body plan.
- (13) The nervous system is well developed. It is formed of longitudinal nerve cords with ganglia. A pair of anterior ganglia form the brain. The longitudinal nerve cords are connected together by transverse connectives.
- (14) They are hermaphrodites, i.e., both male and female reproductive organs are present in the same animal.

(15) Fertilization is internal in them. Self or cross fertilization takes place in them.

(16) Their development is direct or indirect. Endoparasites show usually indirect development with many larval stages. Their life cycle is completed in one or two hosts.

(17) They are free living or parasitic. In parasitic worms adhesive organs like hooks, spines, suckers and adhesive secretions are present.

**Classification of platyhelminthes :** On the basis of digestive tract and free living or parasitic nature phylum platyhelminthes has been divided into three classes –

**Class 1. Turbellaria** (L. turbella, a string)

(1) Most of the turbellarians are free living but some of them are ecto commensal or parasitic, commonly called planarians or flat worms.

(2) The body epidermis is either cellular or syncytial and covered with cilia. Epidermis contains rhabdites.

(3) Segmentation is absent.

(4) Digestive system is present except in a few.

(5) Suckers are absent.

(6) Life cycle is simple, development direct.

Example : *Dugesia*, *Notoplana*, *Bipalium*, *Thysanozoon*, etc.

- *Bipalium* is the only terrestrial planarian.

**Class 2. Trematoda** (Gr. trema, hole)

(1) Ecto or endoparasites of vertebrates; commonly called flukes.

(2) Body mostly oval, unsegmented.

(3) Body wall without cilia, but covered by a thick, resistant, syncytial tegument.

(4) Suckers, and often hooks and spines, present for attachment to host tissues.

(5) Sense organs usually absent in adults.

(6) Digestive system well developed with terminal mouth, but no anus.

(7) Mostly hermaphrodite. Life cycle simple or complicated.

Examples : *Polystomum*, *Fasciola*, *Schistosoma* (blood fluke of man and other mammals), *Opisthorchis*, etc.

- *Opisthorchis sinensis* is commonly known as chinese liver fluke of man.

**Class 3. Cestoda**

(1) All endoparasites. Mostly in alimentary canal of vertebrates; commonly called tapeworms.

(2) Body long and slender, tape-like, usually divided into small segments (= proglottids).

(3) Body wall non-ciliated, with a thick tegument.

(4) Anterior end with suckers and other attachment organs.

(5) No mouth, digestive system absent, digested liquid food is absorbed from host tissues by diffusion through body wall.

(6) Sense organs absent.

(7) Each proglottid contains one or two complete sets of hermaphrodite (bisexual) reproductive organs.

(8) Life-cycle usually complicated with alternation of hosts. Embryo hooked.

Examples – *Taenia*, *Echinococcus*, *Hymenolepis*, *Diphyllobothrium*, *Echinococcus*, *Dipylidium*.

□ *Hymenolepis* is dwarf tapeworm. It is monogenetic tapeworm of man.

□ *Dipylidium* is dog tapeworm.

□ *Diphyllobothrium* is the largest tapeworms.

□ *Echinococcus* is also called hydatid worm. Its hydatid cyst shows exogenous as well as endogenous budding. Parasite of small intestine of dogs, cats, etc. It has only 3-4 proglottids.

## Some representative animals

### Planaria

(1) *Dugesia* (Planaria) is found commonly in freshwater ponds, lakes, streams and shallow rivers.

(2) Planaria are gregarious, i.e., they live in groups.

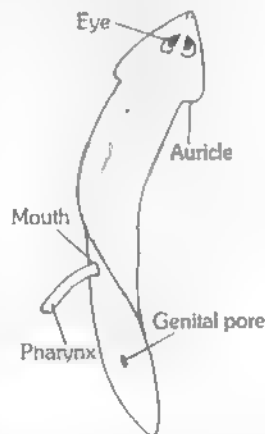
(3) The head bears a pair of lateral projections called auricles.

(4) The mouth opens on the mid ventral surface near the middle of the animal.

(5) The pharynx is a tubular structure that can be everted beyond the mouth.

(6) Planarians have remarkable power of regeneration.

(7) If an individual is cut transversely into two parts, the anterior fragment will regenerate a new tail and a posterior piece will develop a new head.



(8) Neoblast cells found in **Fig : 1.7-15 *Dugesia* (planaria)** planarians which is help in regeneration.

### *Fasciola hepatica*

(1) *Fasciola hepatica*, commonly known as sheep liver fluke is an endoparasite of sheep which reside in the liver and bile duct.

(2) The liver fluke has a dorsoventrally flat, unsegmented body with two suckers, oral sucker (anterior sucker) and acetabulum (ventral sucker).

(3) Liver fluke is covered with a cuticle, lacks ciliated epidermis.

(4) There are three permanent apertures on the body-mouth (surrounded by oral sucker), genital pore (located between the two suckers), excretory pore (At the extreme posterior end). During breeding season a temporary opening, the aperture of Laurer's canal is also developed. Laurer's canal is present between the genital aperture and the uterus.

(5) Suctorial pharynx with bifurcated intestine. A large number of caeca or diverticulae arise from each branch of intestine

(6) Digestion is holozoic. The parasite obtains nourishment from bile, blood, lymph and epithelial cells

(7) Respiration is anaerobic.

(8) Excretion occurs with the help of flame cells.

(9) *Fasciola* is a digenetic endoparasite. Its primary host is sheep causing 'liver rot' and the secondary or intermediate host is the snail of genus *Limnaea* and *Planorbis*.

(10) *Fasciola hepatica* is a hermaphrodite. Male has a pair of testes and female has an ovary, vitelline gland for yolk formation and mehlis's gland for lubrication.

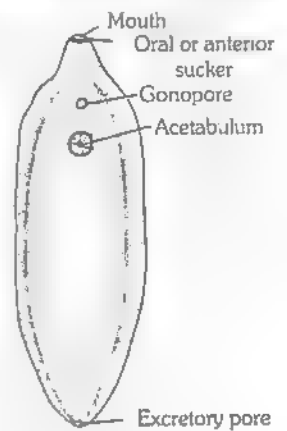
(11) Fertilization is internal. Cross fertilization commonly occurs

(12) Different larval stages of *Fasciola hepatica* according to development sequence are : miracidium-sporocyst-Redia-Cercaria-Metacercaria.

(13) Stage in the life cycle of *Fasciola* when it infects intermediate host (snail) is miracidium and primary host is metacercaria.

(14) Miracidium and cercaria larva are free swimming form in water. Redia and sporocyst are formed in snail.

(15) *Fasciola* exhibits both alternation of generation and alternation of host.



**Fig : 1.7-16 *Fasciola hepatica***

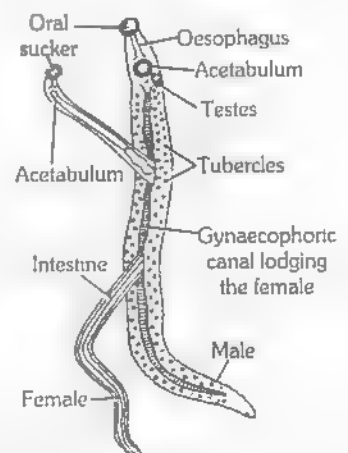
### *Schistosoma*

(1) *Schistosoma* is commonly known as human blood fluke and it is found in the blood vesseles and hepatic portal system of man, cat, pig, dog, etc

(2) Phenomenon of sexual dimorphism occurs. Thus male and female are separate but they live in close association.

(3) Male is flattened while female is slender. Both possess oral and ventral suckers.

(4) The ventral folding from the male's body forms a groove known as 'Gynaecophoric canal' in which the female individual lives.



**Fig : 1.7-17 *Schistosoma* both male and female**

(5) Blood fluke feeds on blood. It respire anaerobically. Excretion occurs with the help of flame cells.

(6) Blood fluke is digenetic, primary host is man and secondary host is snail.

(7) Fertilization is internal. After fertilization the egg develops into miracidium larva which is free swimming. Later on it penetrates snail body and get converted into cercaria larva. The cercaria infect man by penetrating his skin.

(8) Redia and metacercaria stage do not occurs in blood fluke.

(9) Blood fluke causes schistosomiasis or bilharzia.

### ***Taenia solium***

(1) *Taenia solium* is commonly known as pork-tape-worm.

(2) Adult tapeworm lives in the small intestine of man (primary host), larval stage in the secondary or intermediate host pig or cattle

(3) *Taenia solium* possesses elongated ribbon or tape like segmented body (pseudometamerism).

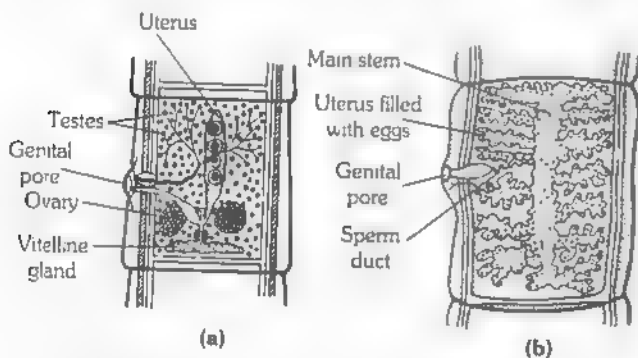
(4) Body is divided into three parts, namely scolex, neck and strobila. Scolex has a rostellum bearing two circles of chitinous hooks and four suckers for holding onto the host. Neck is the region of proliferation of new proglottids. Strobila is long tapering part having large number of proglottids. Proglottids are of three types-young, mature and gravid.

(5) Young or immature proglottids are behind neck without reproductive organs.

(6) Mature proglottids are in the middle having reproductive organs, both male and female.

(7) Gravid proglottids (rectangular in shape) are with branched uterus containing fertilized eggs.

(8) Apolysis is the process of separation of gravid proglottids.



**Fig : 1.7-18 (a) Mature proglottid, (b) Gravid proglottid**

(9) Body wall lacks a cellular epidermis. It consists of cuticle (parasitic adaptation), musculature and mesodermal tissue called parenchyma.

(10) Digestive system is simple without alimentary canal. Food is absorbed through body surface.

(11) Respiration is anaerobic in *Taenia solium*.

(12) Flame-cells (solenocytes) are excretory in function.

(13) All tapeworms are hermaphrodites, and a complete reproductive system occurs in each mature proglottid. Fertilization is internal, cross type within the same proglottid or between two proglottids of the same strobilla

(14) The fertilised eggs develop into an embryo that gets covered by a shell. The shelled embryos are called onchospheres. Secondary host pig acquires infection by ingesting the onchospheres. Hexacanth is developed in shell with six hooks.

(15) Hexacanth stage is the infective stage to pig. In the stomach of pig, hexacanth will be released, it goes through blood circulation and on reaching muscles get encysted in the form of bladderworm (cysticercus). Human host gets infection by eating raw or poorly cooked 'measly pork'. Cysticercus is infective stage to man.

(16) Cysticerci in pig muscle can remain viable for several years.

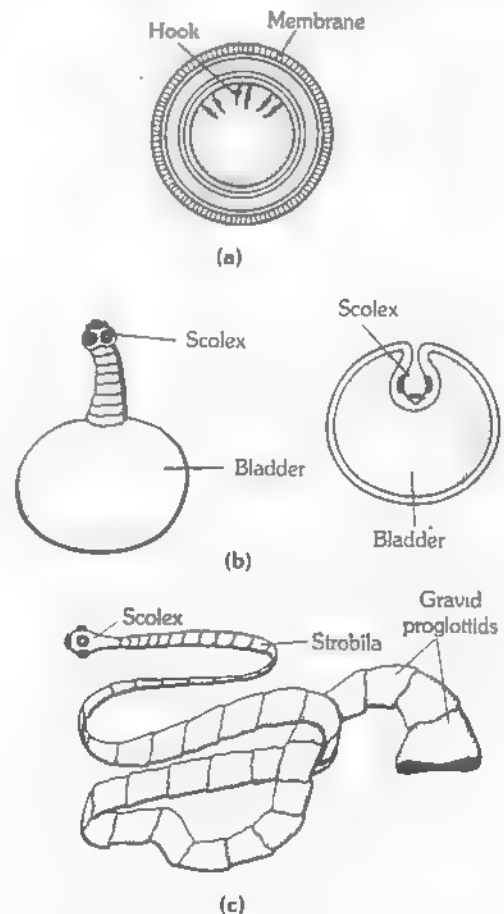
(17) *Taenia saginata* (*Taeniarhynchus saginatus*) is commonly known as 'the beef tapeworm'.

(18) Like *Taenia solium*, it is digenetic, man is the primary host and cattle is the intermediate host.

(19) It is also called 'unarmed tapeworm' because the scolex does not possess hooks.

(20) During infection with taenia necrosis of brain and epilepsy may appear.

(21) The disease caused by bladderworm is known as cysticercosis. Cysticercosis is more dangerous than taeniasis.



**Fig : 1.7-19 Life cycle of *Taenia solium* (a) Onchosphere (b) Bladderworm (Cysticercus) (c) Adult tapeworm**

Table : 1.7-4 Common Names

<i>Fasciola hepatica</i>	– Sheep liver fluke
<i>Fasciola gigantica</i>	– Cattle liver fluke
<i>Schistosoma mansoni</i>	– Human blood fluke
<i>Fasciolopsis buski</i>	– Intestinal fluke
<i>Paragonimus westermani</i>	– Lung fluke
<i>Taenia solium</i>	– Pork tapeworm
<i>Taenia saginata</i>	– Beef tapeworm
<i>Echinococcus granulosus</i>	– Dog tapeworm

## Phylum Aschelminthes (Nemathelminthes)- The round worms

(Gk. *nema* = thread; *helmin* = worm)

**Brief History :** Ancient people were familiar with certain large-sized nematode parasites of domestic animals. Minute nematodes were discovered only after the invention of microscope. Linnaeus (1758) included these in "Vermes" Rudolphi (1793, 1819) included these under "Nematoidea" Gegenbaur (1859) ultimately proposed "Nemathelminthes" for these.

### General Characters

1) Many endoparasites of various animals and plants; others free-living and widely distributed in all sorts of water and damp soil.

(2) Mostly minute or small; some large (1 mm to 25 cm); some upto several meters long.

(3) Slender, cylindrical, elongated body usually tapering towards both ends, and unsegmented.

(4) Body wall formed of a thick, tough and shiny cuticle, a syncytial hypodermis beneath cuticle, and innermost layer of peculiar, large and longitudinally extended muscle cells arranged in four quadrants.

(5) Triploblastic, bilaterally symmetrical, pseudocoelomate, false coelom derived from embryonic blastocoel, unsegmented.

(6) Straight alimentary tract terminal mouth and anus. These are first animals to have complete gut.

(7) 'Tube within a tube body' plan, organ-system grade of body organization.

(8) Circulatory system and respiratory organs absent. A simple excretory system consists of protonephridia, comparatively simpler or complicated sensory organs, and a well-developed nervous system present

(9) Reproductive system well-developed. Usually unisexual with sexual dimorphism.

(10) Many kinds of Nematodes are parasites of useful plants and domestic animals. Some of these are pathogenic to their hosts, causing serious diseases. Even man is a host for more than 50 species, of which *Ascaris lumbricoides* and *Enterobius vermicularis* (pin worm) are very common. Other common human nematodes are *Wuchereria* which causes Filariasis, *Trichinella* causing trichinosis, and *Ancylostoma* causing hookworm disease.

**Classification of Nemathelminthes :** On basis of the presence or absence of some specialized sense organs and caudal glands, and characteristics of excretory system, nematodes are classified into two classes –

### Class 1. Phasmidia or Secernentea or Rhabditea

(1) Mostly parasitic

(2) Possess a pair of unicellular, pouch-like sense organs, called phasmids, near hind end of body.

(3) Another pair of reduced, pore-like sense organs, called amphids, present near anterior end.

(4) Excretory system with paired lateral canals.

(5) Caudal glands absent.

Examples – *Ascaris*, *Enterobius*, *Ancylostoma*, *Wuchereria*, *Trichuris*, *Trichinella*, *Dictyophyma*, *Rhabditis*, *Necator*, *Gnathostoma*, *Dracunculus*, *Loa*, etc.

### Class 2. Aphasmidia or Adenophorea or Enoplea

(1) Mostly small, free-living.

(2) No phasmids

(3) Amphids spiral, cord like or disc like, seldom pore like.

(4) No lateral excretory canals.

(5) Caudal glands present.

Examples : *Enoplius*, *Dorylaimus*, *Mermis*, *Halichoanolaimus*, *Monohystera*, *Desmoscolex*, etc.

## Some representative animals

### Ascaris

(1) *Ascaris lumbricoides*, the common roundworm belong to the class Rhabditea of the phylum Nemathelminthes. It is the most common endoparasite in the small intestine of human beings. It is monogenetic, i.e., without any secondary host. The worm is more common in children.

(2) The body is elongated, unsegmented, cylindrical with tapering ends and four streaks—two lateral, one ventral and one dorsal

(3) Sexes are separate with sexual dimorphism. Male is smaller than female with curved tail, two penial setae (copulatory organs) and cloaca. Female is with straight posterior end of the body and posterior transverse anus and separate gonopore situated ventrally 1/3 from the anterior end. In both the excretory pore is situated mid-ventrally, a little behind the mouth. Ventral surface of male bears fifty pairs preanal and five pairs postanal papillae. These sensory papillae are absent in female.

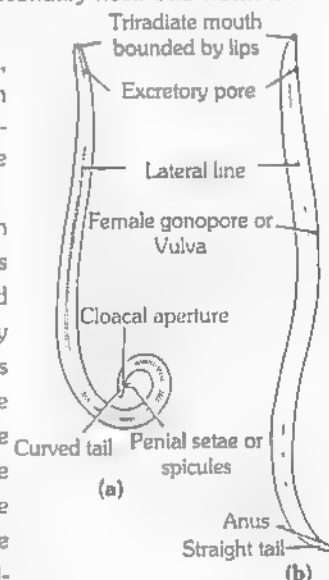


Fig : 1.7-20 *Ascaris*  
(a) Male (b) Female

(4) Mouth both in male and female is terminal, triradiate surrounded by three denticulate lips. One median dorsal and two ventrolateral. Dorsal lip bears two sensory double papillae (tangoreceptors). Both sensory papillae and amphids (chemoreceptors) are present on ventrolateral lips.

(5) Body wall consists of outer cuticle, middle epidermis and inner longitudinal muscle layer. Circular layer is absent. Cuticle is thick which protects the body of the parasite from mechanical injury and also resistant to action of digestive enzymes of the host. The epidermis is syncytial (coenocytic) with scattered nuclei and without partition walls.

(6) The body cavity of *Ascaris* is pseudocoel formed by vacuoles originated from persistent embryonic blastocoel.

(7) There is no alimentary canal and digestive gland. The parasite absorbs digested food of the host so there is no need of digestive organs. Absorption occurs through the general body surface. Salivary glands do not occur in *Ascaris*.

(8) Respiratory system is absent, respiration is anaerobic.

(9) Excretory system is H-shaped. It consists of a single excretory cell or renette cell. Excretory products are ammonia and urea.

(10) Sense organs are simple like labial papillae, cervical papillae, anal papillae, amphids and phasmids.

(11) *Ascaris* is dioecious or unisexual. Testes are single and median, so male *Ascaris* is monorchic (monodelphic). Only anterior part of testis is functional, so testis (also ovary) is telogonic.

(12) *Ascaris* sperm is peculiar without flagellum, tailless, asymmetrical and amoeboidal.

(13) Female *Ascaris* has paired ovaries so female *Ascaris* is didelphic.

(14) Copulation occurs in the intestine of host. Fertilization in the lower part of uterus. The egg is mamillated, oval, m-shape with three protective covering—outer protein layer, middle chitinous shell and inner membrane made of esterified glycosides.

(15) Embryonic development takes place only outside the body of human host in soil because it requires low temperature, more oxygen and suitable moisture.

(16) Inside the shell the zygote develops into rhabditiform larva or first stage juvenile in 10-14 days.

(17) The larva of first stage is not infective. It rests for a week and completes first moult within egg and becomes second stage rhabditiform larva which is infective.

(18) The transmission of infective stage through embryonated egg takes place by contaminated food and water.

(19) The embryonated egg passes into the intestine of man and second stage larva hatches out from the egg.

(20) Three types of migration by *Ascaris* larva are—primary migration, secondary migration and aberrant migration.

(21) Primary migration is from intestinal wall → hepatic portal → liver → hepatic vein → heart → pulmonary artery → lungs

(22) Secondary migration is from lungs back to intestine of the host ; lungs → bronchi → trachea → pharynx → gullet → oesophagus → stomach → intestine.

(23) In lungs, larva complete its second and third moulting (becomes third and fourth stage larva). In small intestine it completes fourth or final moulting and becomes fifth stage of larva.

(24) Duration of wandering journey from intestine to intestine is about three weeks. Within 8-10 weeks adult *Ascaris* starts reproduction.

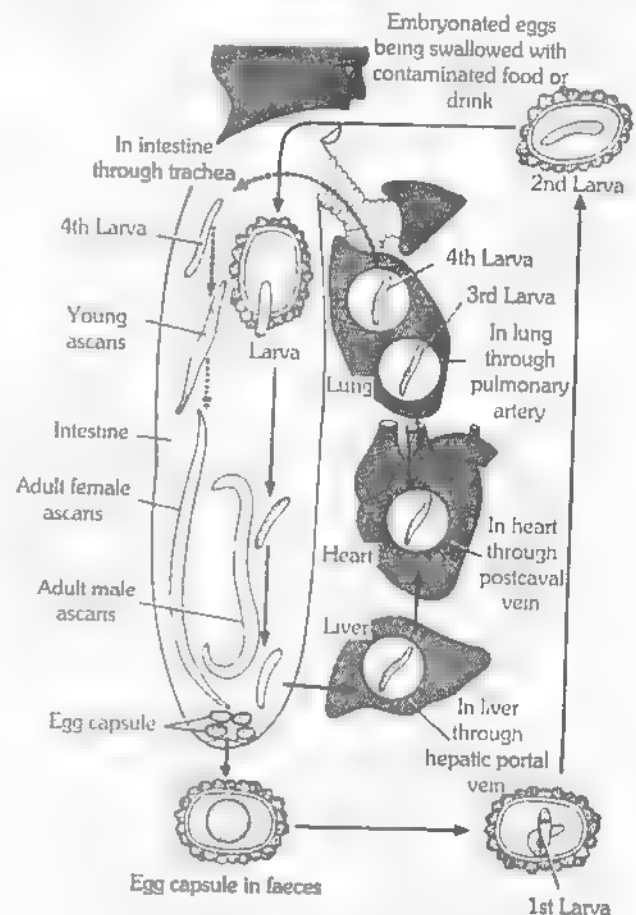


Fig : 1.7-21 Life cycle of *Ascaris*

(25) Aberrant migration is the migration from lungs to brain, spinal cord, eyes, etc.

(26) *Ascaris* is pathogenic. It causes the disease, ascariasis. Most pathogenic larva of *Ascaris* is fourth stage larva.

(27) Main symptoms of ascariasis are—abdominal discomfort, nausea, vomiting, diarrhoea and colic pain.

(28) Toxin produced by *Ascaris* may interfere with protein digestion.

(29) Ascariasis can be treated by antihelminthic drugs such as oil of *Chenopodium*, Santonin, Antipar, Tetrachloroethylene, Alcopar, Decaris, Diethylcarbamazine, etc.

#### Some other nematode parasite :

***Ancylostoma duodenale*** : It is an endoparasite of human small intestine. The parasite is monogenetic. It is popularly called old world hookworm. Adults live in the intestine of man and feed upon blood. No secondary host. Juveniles penetrate through the skin of hand and feet. It causes 'Ancylostomiasis'.

**Wuchereria bancrofti** : It is a digenetic parasite. Human being are primary host while female mosquito mostly of *Culex* and *Aedes* species is the secondary or intermediate host.

Adults live in human lymph vessel and lymph glands. It is a viviparous nematode, larvae called 'microfilaria'. Larvae appear in cutaneous blood (superficial blood) in midnight. Presence of few worms not harmful. They block lymph glands and lymph vessels, swell body parts like arms, scrotum and mammary glands. This results in the disease 'Elephantiasis' or 'Filariasis'.

**Enterobius Vermicularis (Pin worm)** : This worm inhabits human caecum, colon, appendix and rectum. It is monogenetic, no intermediate host. Eggs contain rhabditiform larva. It causes 'Oxyuriasis', the main symptom being itching of anal parts.

**Dracunculus medinensis** : It is a digenetic endoparasite with man being the primary host and cyclops as the secondary or intermediate host. It is also called 'Fiery serpent'. The adult worms occur in the subcutaneous tissue, especially of arms, shoulders and legs, forming blisters. Female is very long while male is short. The guinea worm disease has been eradicated from India. The last case was reported from the Jodhpur district of Rajasthan in July 1996.

**Loa loa (Eye worm)** : It is a filarial roundworm of central and Western Africa. The adult migrates through the subdermal connective tissues of human host. Sometimes they pass across the eyeball. Local swelling accompanies these migrations. Tabanid flies act as transmitting vectors.



Fig : 1.7-22 Adult eye worm, *Loa loa*, from eye

Table : 1.7-5 Common Names

<i>Ascaris</i>	– Common roundworm
<i>Ancylostoma</i>	– Hookworm
<i>Necator</i>	– Hookworm
<i>Wuchereria</i>	– Filarial worm
<i>Enterobius (Oxyuris)</i>	– Pinworm
<i>Trichuris</i>	– Whipworm
<i>Dracunculus</i>	– Guinea worm
<i>Loa loa</i>	– Eye worm
<i>Strongyloides</i>	– Thread worm

## Phylum Annelida – The segmented Animals

(*L.annulus* = ring, *eidōs* = form)

**Brief History** : Linnaeus (1758) included all soft-bodied worms in "*Vermes*". Lamarck (1801) established phylum annelida for higher types of worms.

### General characters

- (1) Annelids are bilaterally symmetrical animals.
- (2) They have organ-system grade of organization.
- (3) They are coelomate (schizocoelomate) animals.
- (4) They have triploblastic body wall.

(5) The muscle layers are thick in the body wall. Hence the body wall is said to be dermomuscular.

(6) The body is divided into a numerous segments called the metameres or somites. The segmentation is known as metamerism.

(7) The body is covered with a thin cuticle.

(8) Locomotory organs are setae.

(9) Digestive system is well developed. These have tube-within-a-tube body plan.

(10) Blood vascular system is a closed type

(11) Excretory system is formed of segmentally arranged nephridia.

(12) These always show cutaneous or skin respiration.

(13) Nervous system is formed of a pair of cerebral ganglia (brain) and a double ventral nerve cord.

(14) Mostly annelids are hermaphrodites. Fertilization is generally cross and may be external or internal.

(15) The gonoducts are formed from coelom (coelomoducts). The coelomoducts have connection with nephridia.

(16) Regeneration is common character in this phylum.

(17) Their development is direct or indirect and includes a free-swimming trochophore larva.

**Classification of annelida** : On the basis of position and arrangement of setae when present, absence and presence of sense organ, phylum annelida has been divided into four classes –

**Class 1. Polychaeta** (Gr. *polus*, many, *chaite*, hair)

- (1) Polychaeta are marine and carnivorous.
- (2) Body is elongated and segmented.
- (3) Head consists of prostomium and peristomium and bear eyes, tentacles, cirri and palps, etc.
- (4) Setae are numerous and are borne upon lateral prominences of the body wall known as parapodia.
- (5) Locomotory organs are parapodia.
- (6) Clitellum is absent.
- (7) Cirri or branchiae or both may be present for respiration.
- (8) Coelom is spacious usually divided by inter segmented septa.
- (9) Alimentary canal is provided with an eversible buccal region and protrusible pharynx.
- (10) Excretory organs are segmentally paired nephridia.
- (11) Sexes are separate.
- (12) Fertilization is external; free swimming larval stage is trochophore.
- (13) Asexual reproduction occurs by budding.

Examples : *Nereis*, *Aphrodite*, *Polynae*, *Chaetopterus*, *Glycera*, *Arenicola*, *Amphitrite*, *Terebella*, *Sabella*, *Eunice*, etc.

❑ *Arenicola*, *Amphitrite* and *Terebella* have external gills.



□ *Chaetopterus* exhibits luminescence and great power of regeneration.

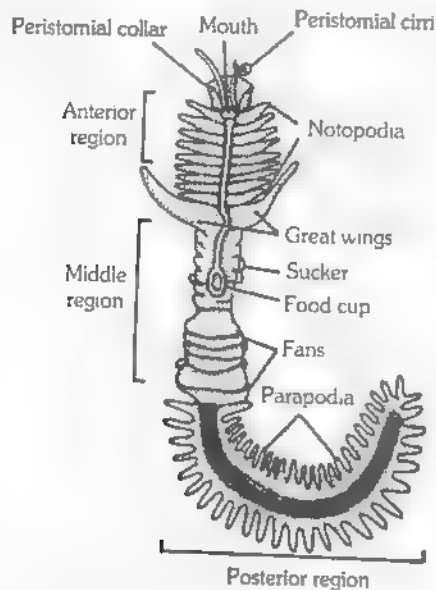


Fig : 1.7-23 *Chaetopterus*

### Class 2. Oligochaeta (Gr. oligi, few)

- (1) They are mostly terrestrial or some fresh water forms.
- (2) Body has conspicuous external and internal segmentation.
- (3) Distinct head, eyes and tentacles are absent.
- (4) Parapodia are absent.
- (5) Locomotory organs are setae.
- (6) Setae are usually arranged segmentally.
- (7) Clitellum is usually present.
- (8) Pharynx is not eversible and without jaws.
- (9) They are hermaphrodites.
- (10) Development is direct and takes place within cocoons secreted by clitellum.
- (11) No free larval stage

Examples : *Tubifex*, *Dero*, *Pheretima*, (Indian earthworms), *Lumbricus* (European earthworm).

□ *Tubifex* and *Dero* are fresh water forms. *Tubifex* can live in polluted water where oxygen availability is poor because it has a large amount of haemoglobin in blood.

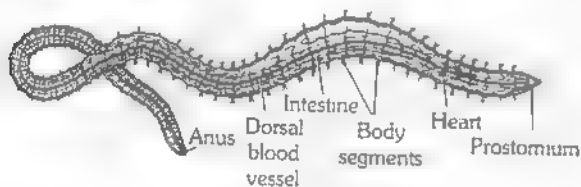


Fig : 1.7-24 *Tubifex*

### Class 3. Hirudinea (L. hirudo, a leech)

- (1) This class includes mostly ectoparasitic and fresh water forms, while few are marine, feeding upon fishes and other animals.

(2) Body is elongated usually flattened dorso-ventrally or cylindrical.

(3) Body consists of definite number of segments, each segment breaks up into 2 to 4 rings or annuli.

(4) Parapodia and setae are absent.

(5) Body is provided with an anterior and a posterior sucker, both situated ventrally.

(6) Coelom is reduced by botryoidal tissue.

(7) Mouth opens on the ventral surface in the anterior sucker, while anus opens dorsal to the posterior sucker.

(8) Locomotory organs are suckers.

(9) Hermaphrodite i.e., sexes united.

(10) Reproduction sexual. Asexual reproduction is unknown.

(11) Eggs are usually laid in cocoons.

(12) Development is direct without free swimming larval stage.

Examples : *Acanthobdella*, *Glossiphonia* (Fresh water leeches), *Pontobdella*, *Haemodipsa*, etc.

□ *Haemodipsa* is terrestrial leech.

□ *Pontobdella* is a ectoparasite on elasmobranchi fishes

□ *Acanthobdella* is a ectoparasite of salmon fish.

### Class 4. Archiannelida (Gr. archi, primitive)

- (1) They are exclusively marine forms.
- (2) Body elongated and worm-like.
- (3) Setae and parapodia are usually absent.
- (4) External segmentation is slightly marked by faint while internal segmentation is marked by coelomic septa.
- (5) Prostomium bears two or three tentacles.
- (6) Unisexual or hermaphrodite.
- (7) Larva is typical trochophore.

Examples : *Polygordius*, *Protodrilus*, *Nerilla*, *Saccocirrus*, etc.

□ *Polygordius* is a primitive Archiannelid or living fossil.

## Some representative animals

### *Pheretima posthuma*

(1) The common Indian earthworm, *Pheretima posthuma* belong to the class oligochaeta of the phylum Annelida. It is found in every part of the world. It lives in damp soil and burrow in lawns, fields, garden etc. rich in humus. Earthworm is nocturnal i.e., active during night

(2) The generic name *Pheretima* was first used by Kinberg in 1867. Our knowledge of *Pheretima* is mainly due to the work of Karm Narayan Bahl (1926).

(3) Body is cylindrical, bilaterally symmetrical, elongated with metameric segmentation. Earthworm shows both external and internal segmentation. The number of segments is about 100-120, the length is about 150 mm.

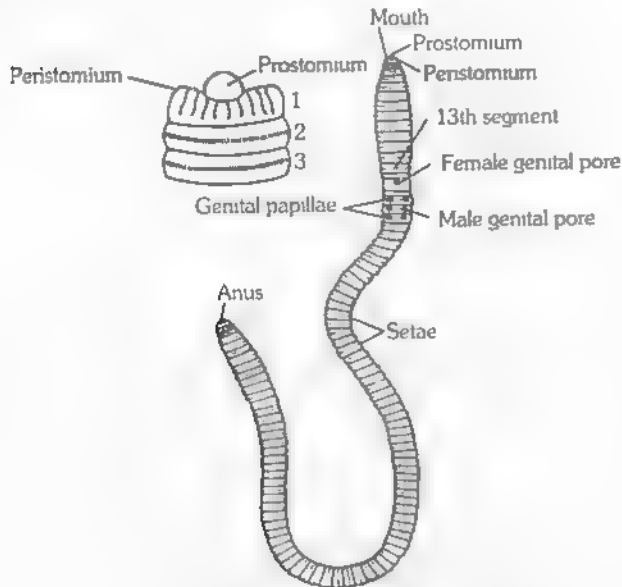


Fig : 1.7-25 *Pheretima* external features

(4) Earthworm is brown or clay-coloured. This is because of the pigment porphyrin. Numerous granules of porphyrin pigment are found scattered in the circular muscle layer of body wall. Porphyrin protects the body from the injurious effects of bright light.

(5) The first segment is peristomium or buccal segment which bears mouth. Anus is located on the last segment.

(6) Three regions in body of earthworm are – Preclitellar region (1 – 13), Clitellar region (14, 15, 16) and Postclitellar region (17 – last).

(7) Nephridiopores of integumentary nephridia 200-250 per segment are found in all segments except the first six. Clitellar segment contains 2000 nephridiopores per segment, so called 'forest of nephridia'.

(8) In the body wall 11 pores are concerned with reproduction. They are – Spermathecal pores in the intersegmental grooves of 5/6, 6/7, 7/8 and 8/9 (4 pairs). Female genital pore midventral on segment 14<sup>th</sup>. Male genital pores ventrolaterally (1 pair) on segment 18<sup>th</sup>.

(9) Male genital papillae are present on segments 17 and 19 (2 pairs).

(10) Body wall is dermomuscular, consisting of cuticle, epidermis, muscular layers and coelomic epithelium. Epidermis consists of tall, columnar cells of four types – Supporting cells (major part), Glandular cells (Goblet and albumin), Basal cells and Sensory cells.

(11) All segments except the first, last and clitellar segment contain setae (perichaetine arrangement). Setae are 'S'-shaped, yellowish and chitinous, 80-120 segment. Setae and contraction of muscles help in locomotion.

(12) The body cavity of earthworm is true coelom (schizocoel) as it is formed by the division of mesoderm. The coelom is filled with milky white alkaline coelomic fluid. Coelomic fluid contains different types of corpuscles. These are granulocytes (phagocytes), most numerous mucocytes, circular nucleated cells (leucocytes) and chloragogen cells (yellow cells).

(13) Chloragogen cells are small, star-shaped, yellow cells concerned with storage of reserve food, deamination of proteins, formation of urea and also excretory (analogous to the liver of vertebrates).

(14) The alimentary canal of earthworm is a straight tube, representing a 'tube within tube plan'. Location of different part of alimentary canal are –

Buccal chamber : 1–2½

Pharynx : 2½–4

Oesophagus : 5–7

Gizzard : 8

Stomach : 9–14

Intestine : 15 onwards

Roof of pharynx contains pharyngeal glands containing chromophil cells secreting mucus and proteases. Gizzard is a thick muscular organ, cavity lined by tough cuticle for grinding. Wall of stomach contains 'calciferous glands' the secretion of which neutralizes the acidity of soil.

(15) Due to presence of typhlosole the intestine is divided into three region –

Pretyphlosolar region, Typhlosolar region, post typhlosolar region.

Intestinal caeca arise from segment 26 and extend forward upto segments 22 or 23.

(16) Typhlosole is a highly glandular, vascular longitudinal ridge increasing the area for absorption of digested food.

(17) Earthworms are omnivorous. Undigested particles as faeces are called as 'casting'.

(18) Blood vascular system of earthworm is closed type. Blood is red in colour, respiratory pigment haemoglobin is dissolved in the blood plasma.

(19) The main longitudinal blood vessels are three –

(i) The dorsal blood vessel

(ii) The ventral blood vessel

(iii) The subneural blood vessel

(20) Important transverse vessels in first 13 segments are –

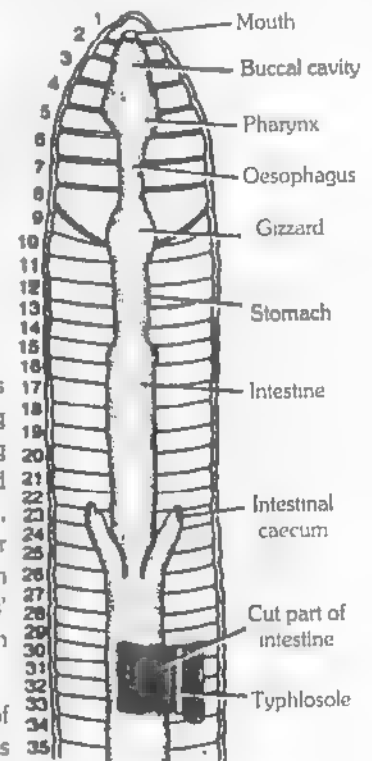


Fig : 1.7-26 Alimentary canal - *Pheretima*

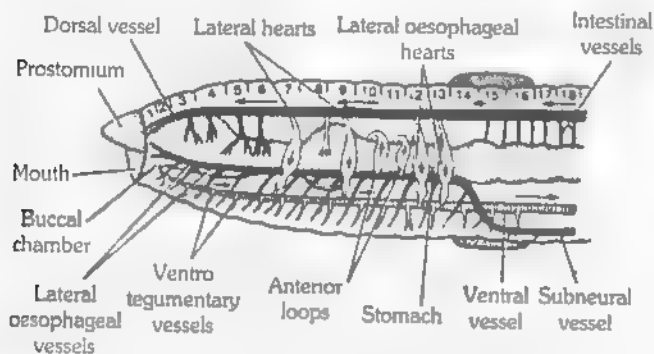
Lateral hearts (segments 7 and 9), Anterior loops (segments 10 and 11) and, Lateral oesophageal hearts (segments 12 and 13).

(21) Dorsal blood vessel is distributive in segments 1 to 13. Flow of blood in dorsal vessel is from posterior to anterior direction.

(22) Ventral vessel is found below alimentary canal, single, blood flows anterior to posterior direction.

(23) Blood glands are three in number and present on 4<sup>th</sup>, 5<sup>th</sup> and 6<sup>th</sup> segments. These produce blood cells and haemoglobin.

(24) Lymph glands are present on both sides of dorsal blood vessel from segment 26<sup>th</sup> and those behind it (one pair per segment, small and whitish). Lymph glands are supposed to produce certain phagocytic cells



**Fig : 1.7-27 Blood vascular system - *Pheretima***  
(After 13<sup>th</sup> segments)

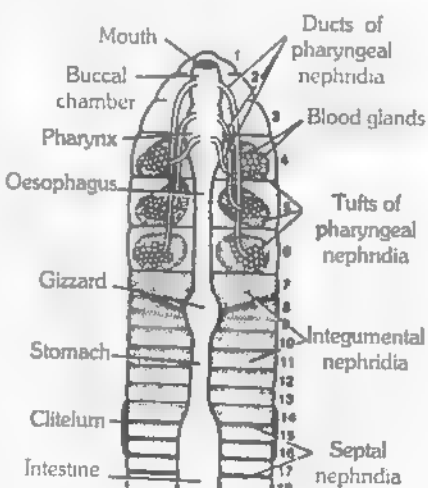
(25) Earthworm respire, but has no respiratory organs, exchange of gases takes place through moist skin. The absorptive area of earthworm is more than its volume, so earthworm does not require any respiratory organ. If the skin of the earthworm dries, it cannot respire. it dies due to asphyxia.

(26) Excretory organs of earthworm are segmental nephridia ectodermal in origin, analogous to vertebrate kidney.

(i) Pharyngeal nephridia are situated in the segments 4, 5 and 6. They open in the anterior part of alimentary canal, i.e. buccal cavity and pharynx. They are without nephrostome and are enteronephric type.

(ii) Integumentary nephridia are scattered in the body wall. They are smallest, V-shaped without nephrostome and are exonephric type.

(iii) Septal nephridia are the largest, attached to both faces of each intersegment septum behind 15<sup>th</sup> segment.



**Fig : 1.7-28 Pharyngeal nephridia - *Pheretima***

(27) Septal nephridia are the only nephridia with nephrostome or funnel. The terminal duct opens into septal excretory canal. Septal nephridia are enteronephric finally excretory products are poured into intestine. Earthworms are mainly ureotelic.

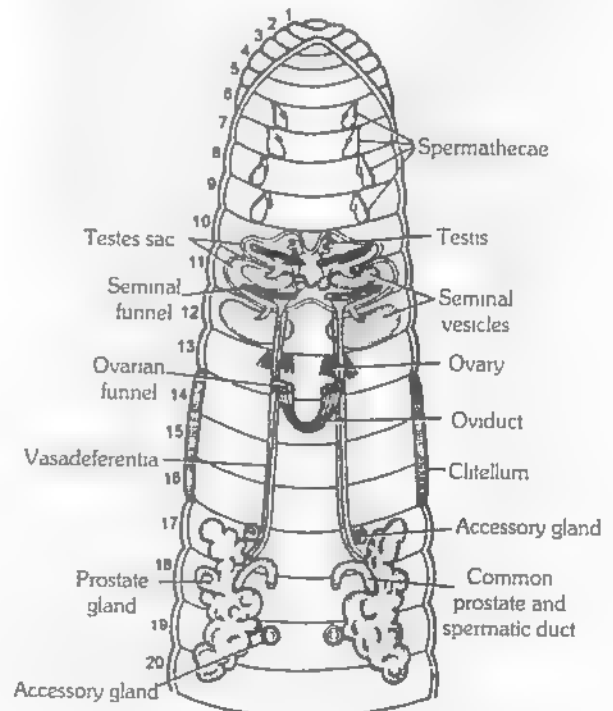
(28) Earthworm has a well developed nervous system; It has a brain but no head. Brain lies above pharynx, made up of a pair of suprapharyngeal (cerebral) ganglia

(29) Earthworm has no eyes, photoreceptors are used to judge intensity and duration of light, do not have the capacity of vision.

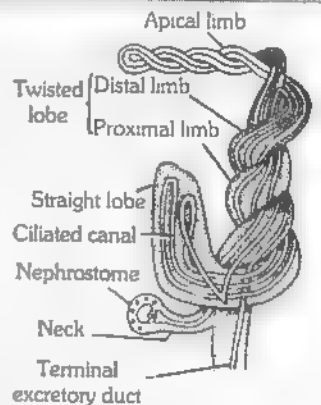
(30) Earthworm are hermaphrodite (monoecious) but fertilization is cross type due to protandrous condition.

(31) In earthworm reproductive system consist of the following organs -

Male organs - Testes two pairs	(segments 10 and 11)
Seminal vesicles	(segments 11 and 12)
Accessory gland	(segments 17 and 19)
Genital papillae	(segments 17 and 19)
Male genital apertures	(segments 18)
Prostate gland	(segments 17-20)
Female organs - Ovary one pair	(segment 13)
Female genital pore	(segment 14)
Spermatheca 4 pairs	(segments 6, 7, 8, 9)



**Fig : 1.7-30 Reproductive organs - *Pheretima***



**Fig : 1.7-29 Septal nephridium - *Pheretima***

(32) Spermatheca are used to store sperms after copulation (open outside on intersegmental groove 5/6, 6/7, 7/8, 8/9).

(33) Copulation occurs between two earthworms generally at night during rainy season. Fertilization is external and occurs in cocoon. Cocoons are formed by glandular clitellum. A cocoon may contain many fertilized eggs, but only one embryo develops, other eggs serve as nurse cells.

(34) Cleavage is holoblastic and unequal, development is direct without any larval stage.

(35) One of the oldest use of earthworm; it is used as bait for catching fish. Earthworms are friends of farmers because they enrich the soil by nephridial excretion, it increases the fertility of soil.

### *Hirudinaria granulosa*

It is commonly known as Indian cattle leech. It is sanguivorous (feed on blood) segmented animal that live in ponds, streams, rice fields etc. It is ectoparasite on cattle and human. The body is soft, flattened and slimy. The dorsal side is yellowish green while the ventral side is orange. Botryoidal tissue is present in coelomic space.

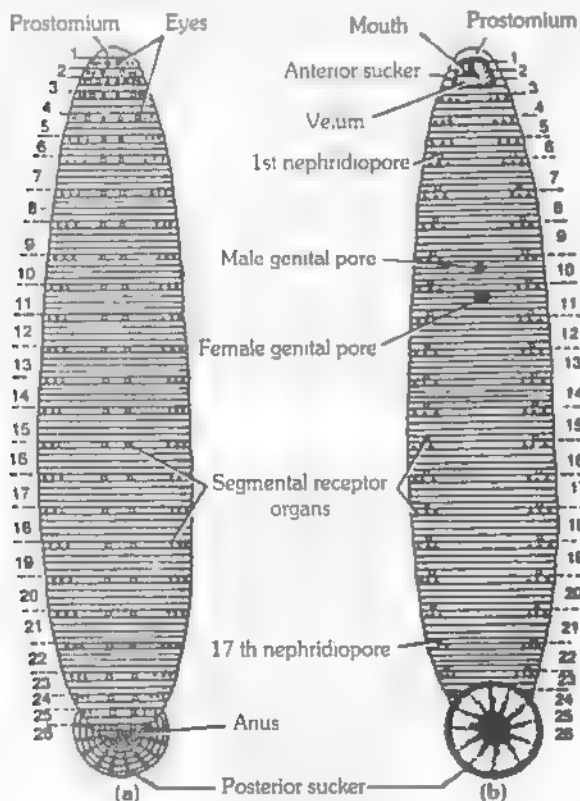


Fig : 1.7-31 Leech - External features (a) Dorsal View (b) Ventral View

The body is divisible into 33 segments. Each segment further appear subdivided superficially by annuli. Each segment from 6-22 bear a pair of ventral nephridiopore. During breeding season a temporary clitellum develops on 9, 10 and 11 segments. The leech bears two suckers. The anterior sucker encloses the mouth. It acts as a feeding locomotory and prehensile organ. The posterior end bears a large disc-shaped sucker that helps in locomotion and anchorage. It comprises the last seven uniannulate segments. Anus lies ahead of posterior sucker. Triradiate mouth is present at its bottom. The saliva of the leech contains an anti-coagulant, called hirudin which

prevents clotting of blood during blood meal. There are present five pairs of eyes on the dorsal surface. It is hermaphrodite but cross-fertilisation occurs. Development is direct. Prof. M.L. Bhatia has given a detailed morphology of *H. granulosa*

### Nereis

It is commonly called clam worm or sand worm or rag worm which is found on the sea shore in the tubular burrow. *Nereis* is unisexual and its reproductive phase is called *Heteronereis*. *Heteronereis* have two regions – epitoke or posterior sexual region and atoke or anterior region without masses of developing gametes. The phenomenon of transformation of *nereis* into *heteronereis* is called epitoky. The gametes are liberated through mixonephridia. Fertilization occurs in sea water. During development trochophore larva is present. The prominent head consists of prostomium and peristomium. The prostomium bears a pair of small tactile tentacles and a pair of stout palp. On the dorsal surface of the peristomium there are present two pair of black eyes. Peristomium has four pairs of long tentacles (cimi). Pharynx is everted for ingestion of food. Each segment bears laterally one pair of fleshy projection, the parapodia, used in swimming. The last segment has an anus. The anal segment is devoid of parapodia but bears a pair of elongated anal cm.

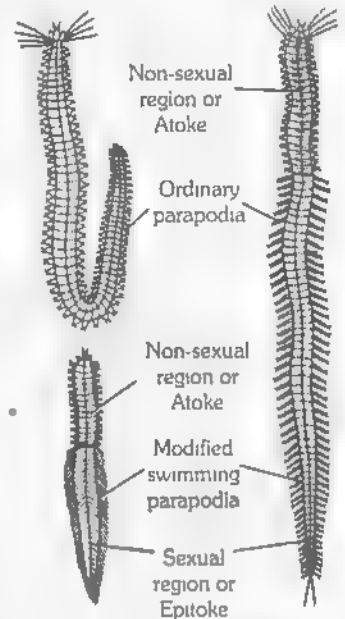


Fig : 1.7-32 *Heteronereis*

### Bonellia

It is a marine worm which lives in the crevices of the rocks. It has only traces of segmentation but sexual dimorphism is extremely exhibited. The female has an ovoid and unsegmented body covered with papillae. It is provided with a prostomial bifurcated proboscis homologous to annelids. There is only one pair of large ventral chitinous setae. The male is small and is reduced to a minute size of *Turbellaria* and lives in the body of the female. The larva of *Bonellia* has the potentialities of both male and female. If they develop independently they become females, but if they come in contact with female, they develop into males.

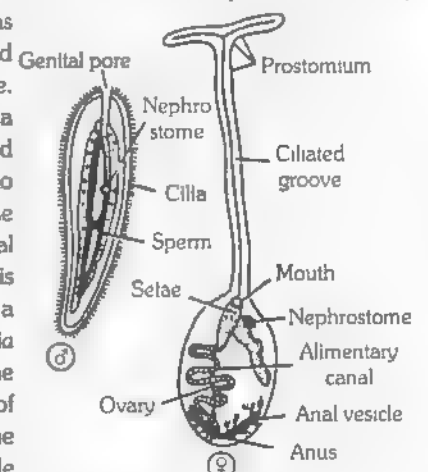


Fig : 1.7-33 *Bonellia*

**Aphrodite**

The *Aphrodite* is a marine polychaete which is commonly called the 'sea mouse'. It is found buried in the mud or sand or crawling on the sea bed. The body is oval, broad and dorso-ventrally flat and consists of 30-35 metameres. The body is covered with scales or elytra which are modifications of dorsal cilia of parapodia and are respiratory in function. The head is small and consists of a peristomium and a prostomium. The prostomium bears a pair of eyes, a short tentacle and a pair of long palps. During movement the animal changes colour from golden to peacock blue. The animal is commonly found in Atlantic and Mediterranean seas.

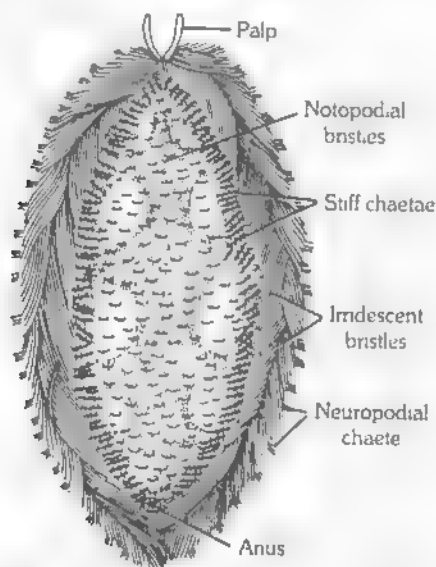


Fig : 1.7-34 *Aphrodite*

Table : 1.7-6 Common Names

<i>Nereis</i>	–	Ragworm
<i>Aphrodite</i>	–	Sea mouse
<i>Polynoe</i>	–	Scale worm
<i>Chaetopterus</i>	–	Paddle worm
<i>Arenicola</i>	–	Lugworm
<i>Glycera</i>	–	Smooth blood worm
<i>Eunice</i>	–	Palolo-worm
<i>Sabella</i>	–	Peacock-worm
<i>Serpula</i>	–	Fan-worm
<i>Pheretima</i>	–	Earthworm
<i>Pontobdella</i>	–	Skate-sucker
<i>Hirudo</i>	–	Medicinal leech
<i>Hirudinaria</i>	–	Cattle leech
<i>Sipunculus</i>	–	Pea-nut worm
<i>Tubificex</i>	–	Blood worm

**Phylum Arthropoda – The animals with jointed feet**

(Gk. *Arthron* = joint; *Podos* = foot)

**Brief History :** Aristotle described a few crabs and other arthropods. Linnaeus included all such animals in his group "Insecta". Lamarck divided this group into three classes – Crustacea, Hexapoda and Arachnida. Finally, Von Seibold (1845) established the phylum Arthropoda for these animals.

**General characters**

(1) Occur widely on land, in air, and in all sorts of water, from snowy tops of high mountains to the depths of ocean. Many are parasites of other animals and plants. Hence, the phylum is of great economic importance.

(2) Bilateral, triploblastic, body segmented and also divided into head, thorax and abdomen. Segmentation marked only externally; number of segments or somites fixed and each has its separate exoskeleton of thick and hard, chitinous cuticle secreted by epidermis of body wall. Head somites always fused.

(3) Each segment basically bears a pair of lateral jointed appendages adapted for food ingestion, locomotion, respiration, copulation, etc.

(4) Muscular system well-developed; muscle fibres always striated.

(5) Digestive tract is complete. Most head appendages form mouth parts with lateral jaws for chewing or sucking. Anus is terminal.

(6) Coelom is reduced to small cavities in excretory and reproductive organs; replaced elsewhere by blood sinuses which merge together to form a large perivisceral cavity – the haemocoel – around viscera. Sinuses form an "open blood vascular system" filled with haemolymph which may contain haemocyanin. Haemocoel communicates with a long tubular and pulsatile, mid-dorsal heart.

(7) Respiration by gills (aquatic forms), or trachea or book lungs (terrestrial forms); by diffusion through body surface in some.

(8) Excretion by coelomoducts or specialized green or coxal glands, or by malpighian tubules. Excretory product is uric acid.

(9) Nervous system is basically similar to the typical annelid plan; head with a brain-ring which is connected to a double ventral nerve cord, having paired segmental ganglia which represent true metamerism. Well-developed sensory organs of various types.

(10) Cilia completely absent. Muscles mostly striated and capable of rapid contraction.

(11) Sexes mostly separate with sexual dimorphism. Paired reproductive organs and ducts.

(12) Fertilization typically internal, in female's body. Eggs megalecithal. Oviparous or viviparous.

(13) Life-cycle includes one or more larval stages that metamorphose into adults.

**Classification of Arthropoda :** On the basis of body shape, degree of segmentation and regionation, and presence or absence of certain appendages (antennae, mandibles and chelicerae), phylum Arthropod is divided into four subphyla; Biggest phylum in regard to the number of species is Arthropoda.

**Subphylum (I) Onychophora** (Gr. Oychos = claw, phoros = bearing)

- (1) Terrestrial walking worms.
- (2) Body cylindrical with indistinct external segmentation.
- (3) Unjointed 14-43 pairs of legs.
- (4) Head not distinct, Oviparous/Viviparous
- (5) A pair of eyes, short antennae and blunt oral papillae.
- (6) Excretory organs are metanephridia which are segmentally arranged
- (7) A living connecting link forming a transitional link between Annelida and Arthropoda

Example . *Peripatus*, *Ophisthopatus*, *Ooperipatus*, etc.

**Subphylum (II) Trilobitomorpha** (Gr. TRIA = Three; LOBOS = lobe; MORPHE = form)

- (1) Most primitive, extinct, marine arthropods of Cambrian to Permian rocks.
- (2) 10 to 675 mm. Long body covered by a hard segmented shell; distinct head of four fused somites bearing a pair of antennae, four pairs of appendages and often a pair of eyes.
- (3) Trunk divided, by two longitudinal furrows, into 3 lobes.
- (4) Abdominal region of 2 to 29 somites and a fused caudal plate or pygidium.
- (5) Each segment, except the last one, bears a pair of biramous jointed appendages

Example – *Trilarthrus*, *Dalmenites*.

**Subphylum (III) Chelicerata** (Gr. CHELA = Claw; CEROS = Horn; ATA = Group)

- (1) Mostly terrestrial, free-living and small-sized.
- (2) Body distinguished into head, thorax and abdomen (= opisthosoma). Head and thorax fused to form a cephalothorax or prosoma
- (3) Cephalothorax with eyes and six pairs of appendages – One pair of clawed and jointed chelicerae in place of mandibles, one pair of pedipalps, and four pairs of walking legs. Antennae absent. Abdomen with or without appendages, but distinguished into a large and broader mesosoma, a small metasoma and a long and narrow, tail-like telson.
- (4) Respiration by gills book-lungs or tracheae.
- (5) Excretion by malpighian tubules or coxal glands, or both
- (6) Sexes mostly separate; females oviparous; development direct or through a larval stage. Divided into three classes on the basis of respiratory organs

#### Class 1. Merostoma

- (1) They are Marine.
- (2) Respiration by gills.
- (3) Cephalothorax with lateral compound eyes median simple eyes and six pairs of usual appendages.
- (4) Abdomen with 5 to 6 pairs of gill-bearing appendages.
- (5) Hind end forms a long bayonet-like telson.

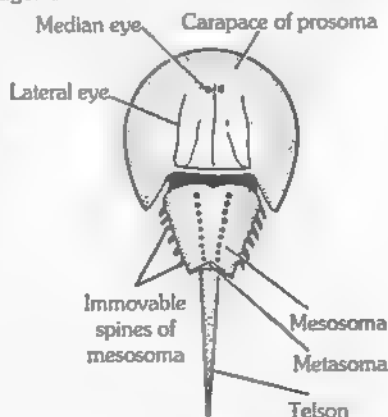


Fig : 1.7-35 *Limulus*

Example– *Limulus* (The king-crab)

□ *Limulus* is a living fossil.

#### Class 2. Arachnida

- (1) Mostly terrestrial; spiders, scorpions, mites, ticks, etc.
- (2) Respiration by book-lungs or trachea.
- (3) Eyes simple
- (4) Abdomen without appendages.
- (5) Many with poison glands and poison fangs, jaws of stings.
- (6) No gills.
- (7) Life-cycle without metamorphosis.

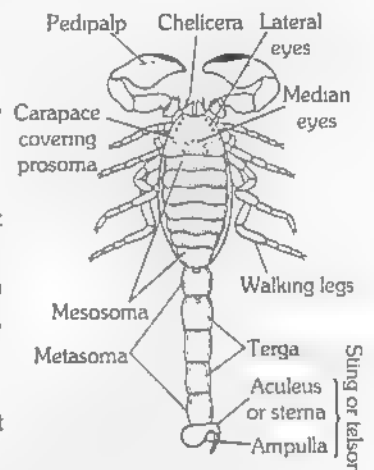


Fig : 1.7-36 Scorpion

Examples– *Palamnaeus*

(scorpion), *Lycosa*, mites, ticks.

□ *Lycosa* is a common web-spinning spider; web-spinning glands are situated in posterior part of abdomen.

#### Class 3. Pycnogonida or Pentapoda

- (1) Small-sized marine sea-spiders.
- (2) Cephalothorax 3-segmented; forms major part of body; abdomen vestigial.
- (3) Suctorial mouth on top of a long proboscis.
- (4) Head usually with 4 pairs of appendages and 4 eyes.
- (5) 5, 6 or 12 pairs of long walking legs.
- (6) No special respiratory and excretory organs.
- (7) Unisexual; females oviparous. Eggs carried by males.

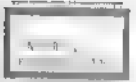
Example – *Nymphon*.

**Subphylum (IV) Mandibulata or Antennata** (L.MANDIBULA = Mandible; ATA =group)

- (1) Body divided into head and trunk, or head, thorax and abdomen.
- (2) Segmentation distinct.
- (3) 1 or 2 pairs of antennae, 1 pair of mandible in place of chelicerae, one or more pairs of maxillae and 3 or more pairs of walking legs.
- (4) Eyes mostly compound.
- (5) Respiration by gills or trachea
- (6) Excretion by malpighian tubules or antennal glands.
- (7) Unisexual; life cycle usually with larval forms. Divided into six classes

#### Class 1. Crustacea

- (1) Mostly aquatic
- (2) Body divided into cephalothorax and abdomen.
- (3) Dorsally, cephalothorax covered by a thick exoskeletal carapace.
- (4) Head of 5 segments, with 2 pairs of antennae, one pair of mandibles and 2 pairs of maxillae; thorax of 2 to 60 distinct or variously fused somites; abdominal somites usually distinct with a posterior telson.



- (5) Appendages mostly biramous.
  - (6) Respiration through body surface or by gills.
  - (7) Excretion by special coxal glands in antennae or maxillae.
  - (8) Mostly unisexual; genital ducts and pores paired; females oviparous.
  - (9) Life-cycle usually with larval forms.
- Examples – *Palaemon*, *Cancer*, *Cyclops*, *Astacus*, *Sacculina*, *Cypris*, *Daphnia*, etc.
- Tiny crustaceans such as *Daphnia* and *cyclops* act as zooplankton which form important link in the food chain in water.

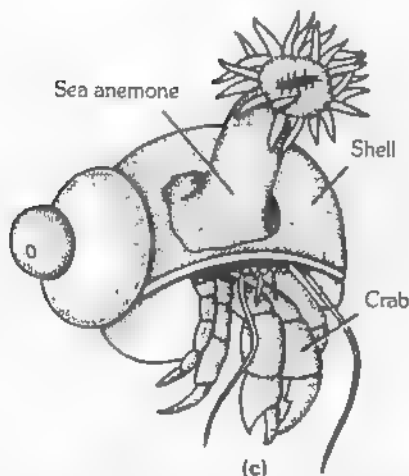
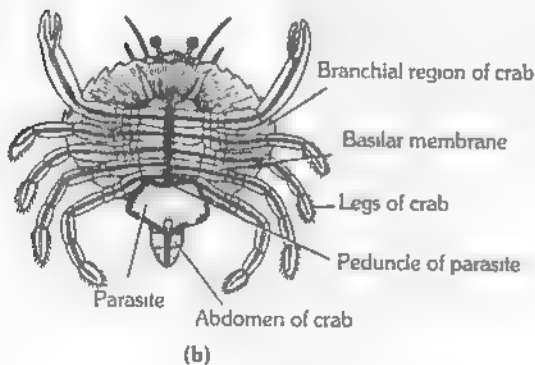
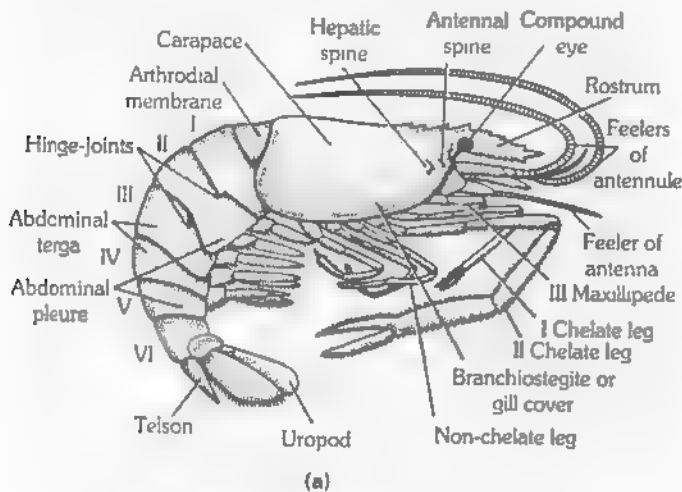


Fig : 1.7-37 (a) Prawn-External features (b) *Sacculina* (on host body) (c) Hermit crab (*Commensalism*)

## Class 2. Insecta

- (1) Aquatic, terrestrial or aerial.
- (2) Body divided into head, thorax and abdomen.
- (3) Segments 6 in head, 3 in thorax and 11 or less in abdomen.
- (4) Legs typically 3 pairs (Hexapoda); aerial forms with one or two pairs of wings.
- (5) Head with 1 pair of large, compound eyes, 1 pair of antennae and variously modified mouth-parts.
- (6) Respiration by branched tracheae
- (7) Excretion by specialized malpighian tubules.
- (8) Unisexual; females oviparous.
- (9) Life-cycle simple or complicated.

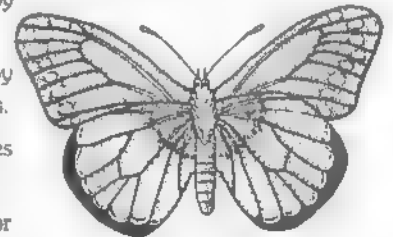


Fig : 1.7-38 Butterfly

Examples – *Periplaneta*, *Musca*, Mosquitoes, locusts, butterflies, bees, wasps, termites, silverfish, beetles, etc.

- Insects are of great economic importance to mankind
- Silverfish is not a fish.

## Class 3. Diplopoda

- (1) Terrestrial.
  - (2) Body long, cylindrical, worm-like.
  - (3) 5-segmented head with 1 pair each of short antennae, mandibles and maxillae; 2 groups of simple eyes.
  - (4) Thorax of 4 segments, each except the first with a pair of joined legs.
  - (5) Abdomen of 9 to 100 or more segments, but each apparent segment is formed by fusion of two and, hence, bears 2 pairs of legs, spiracles, ostia and nerve ganglia.
  - (6) Respiration by tracheae.
  - (7) Excretion by malpighian tubules.
  - (8) Unisexual; gonad single, females oviparous
- Example – *Thyroglytus* (millipede)
- *Thyroglytus* damages the root of crop plants.

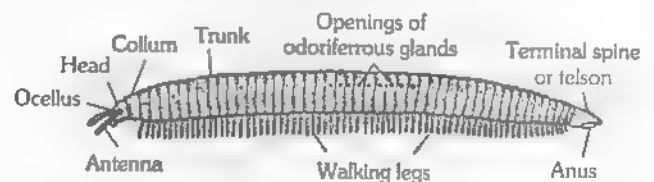


Fig : 1.7-39 *Julus* (millipede)

## Class 4. Chilopods

- (1) Terrestrial.
- (2) Body long, worm-like, somewhat dorso-ventrally flattened and divided into head and trunk

(3) Segments 15 to 181; not fused in pairs; each with a single pair of legs; first pair of legs claw like and each contains a poison gland.

(4) Head with a pair each of long antennae and mandibles, and 2 pairs of maxillae.

(5) Respiration by tracheae.

(6) Unisexual; females oviparous or viviparous. Genital openings mid ventral on last but one segment.

(7) Excretion by malpighian tubules.

Example – *Scolopendra* (centipede).

□ Diplopoda and chilopoda are together kept in myriapoda.

### Class 5. Symphyla

(1) Terrestrial.

(2) Body upto 6 mm. Long; divided into head and trunk.

(3) Head like that of insects, but without eyes.

(4) Trunk of 15 to 22 somites; bears 10 to 12 pairs of legs.

(5) Genital pores mid ventral between legs of 4th pair.

Example – *Scutigrella* (the garden centipede).

### Class 6. Pauropoda

(1) Terrestrial.

(2) Minute, soft and cylindrical, worm like body divisible into head and trunk.

(3) Head with one pair each of branched antennae and unbranched mandibles and maxillae; no eyes.

(4) Trunk of 11 or 12 somites which are dorsally fused in pairs.

(5) Legs 9 to 10 pairs.

(6) Genital pores ventral on 3<sup>rd</sup> trunk segment.

Example – *Pauropus*.

## Some representative animals

### Cockroach (*Periplaneta Americana*)

(1) Cockroach belong to the class insecta of the phylum Arthropoda.

(2) Two species of cockroaches commonly found in India are– *Periplaneta americana* and *Blatta orientalis*. *Periplaneta americana* is the largest and most common species. The generic name *periplaneta* was given by Burmeister in 1838

(3) Cockroaches are nocturnal and cursorial (running). It is cosmopolitan in distribution, but cockroach are more abundant in warm, humid areas.

(4) Body is divided into head, thorax and abdomen. Head is derived by the fusion of six embryonic segments. The part of head between and behind the eyes is epicranium (vertex). The front of head capsule is made up of three unpaired flattened sclerites called frons, clypeus and labrum.

(5) The thorax consist of three segments–prothorax, mesothorax and metathorax. Thorax bears three pairs of jointed appendages and two pairs of wings on mesothorax and metathorax.

(6) Exoskeleton of each segment consists of four chitinous plates called sclerites. The dorsal sclerite is called tergum or tergite, ventral sclerite is sternum or sternite and two lateral sclerites are called pleura or pleurites. The dorsal plate of the thorax is called notum

(7) The antenna is made of many segments, podomeres. The first segment is scape (largest), second pedicel and rest many jointed flagellum. Antenna is a thigmoreceptor which is sensitive to touch.

(8) Mouthparts of cockroaches are mandibulate type or cutting and chewing type. Mouthparts consists of labrum (upper lip), labium (lower lip), maxillae (segmented and resemble to a leg), mandibles and hypopharynx (tongue).

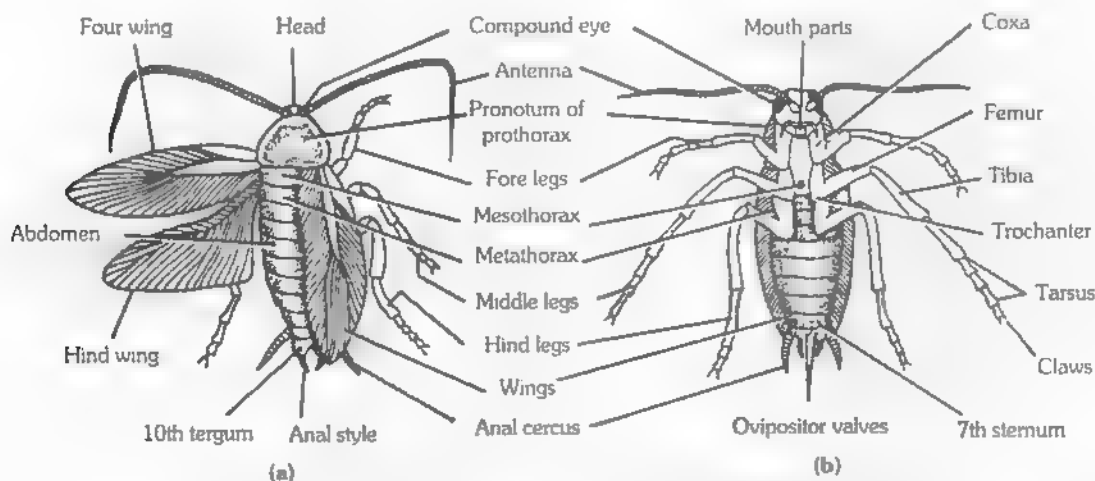


Fig : 1.7-40 *Periplaneta* - External features (a) Dorsal view (b) Ventral view



(9) The main structures of mastication (chewing) are mandibles which are short with teeth

(10) Maxilla consists of cardo, stipes, galea, lacinia and 5-segmented maxillary palp

(11) Labium (= second maxilla) consists of submentum, mentum, prementum, palpiger, paraglossa, glossa and three jointed labial palp.

(12) Glossa and paraglossa are together called lingula. They push the masticated food into buccal cavity.

(13) A common salivary duct opens at the base of the hypopharynx.

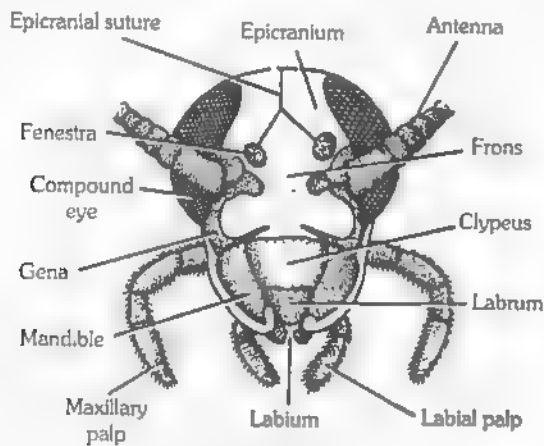


Fig : 1.7-41 *Periplaneta* - head

(14) Each leg is formed by five segments, viz, coxa, trochanter, femur, tibia and tarsus (tarsus is made by five tarsomeres). Attached to the last tarsomere called pretarsus and it bears, a soft lobe called arolium or pulvillus and a pair of claws is present. They are helpful in moving on smooth surfaces. Plantulae are present on tarsus and act as thermoreceptors.

(15) The most swollen segment in the leg of cockroach is coxa. The longest segment in the leg of cockroach is tibia.

(16) In adult cockroach abdomen is made up of ten segments. But in embryonic stage eleven segments are present. The 11<sup>th</sup> segment of embryo is represented in adult by podical plates.

(17) In male cockroach, eighth and ninth terga are overlapped by seventh tergum. In female seventh, eighth and ninth sterna are fused to form a brood pouch. Seventh sternum of brood pouch forms a pair of gynavalvular plates.

(18) Anal cerci bear minute sensory hairs which are sensitive to sound and other vibrations.

(19) Anal cerci, a pair of many jointed structures are present on the tergite of 10<sup>th</sup> segment in both sexes.

(20) Anal styles, a pair of small, spine-like unjointed structures are present on sternite of 9<sup>th</sup> segment in males only.

(21) Cockroach has two pairs of wings. The first pair (mesothoracic) are thick, hard and leathery, protective in function called tegmina (= elytra). Second pair (metathoracic) are thin, soft and membranous.

(22) Cockroach does not fly, but the wings help in escaping from danger

(23) Body wall of cockroach is made up of two layers, outer cuticle and inner hypodermis.

(24) Cuticle is invaginated forming endoskeletal elements like tentorium in head and apodemes in thorax. They provide sites for attachment of muscles. The cuticle has three distinct layers, outer primary cuticle or epicuticle, middle thick exocuticle and inner thick endocuticle.

(25) Hypodermis is a single layered epithelium. Some of its cells are modified into large oval trichogen cells concerned with secretion of movable bristles on the body of cockroach

(26) The body cavity of cockroach is a haemocoel, filled with blood.

(27) The alimentary canal of cockroach is divisible into three parts, viz, foregut, midgut and hindgut.

(28) Foregut (stomodaeum) is differentiated into five parts – buccal chamber, pharynx, oesophagus, crop and gizzard. Gizzard is muscular and internally provided with six cuticular teeth which crush the food

(29) Midgut (mesenteron or ventriculus) is short, tubular, lined with glandular endoderm. At anterior end of mesenteron there are eight blind glandular hepatic caecae which secrete digestive enzymes. Internally mesenteron is not lined by cuticle but it is covered by a very thin and transparent peritrophic membrane formed of chitin and proteins.

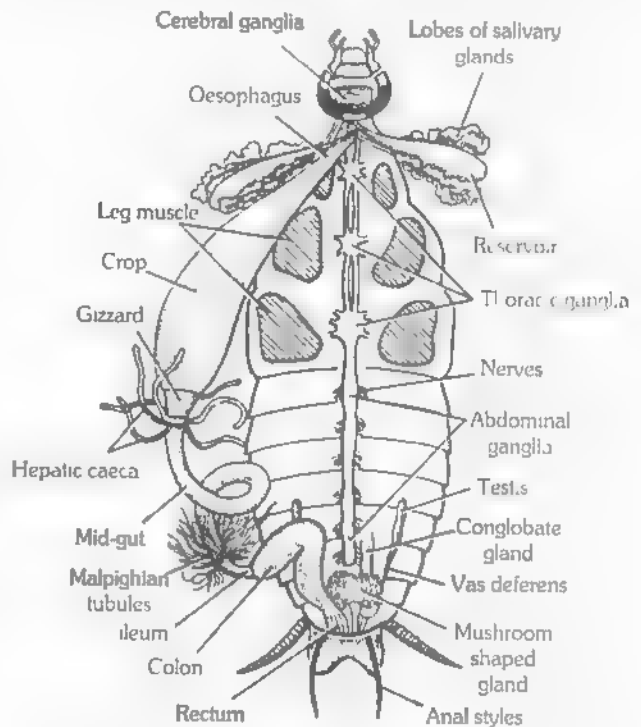


Fig : 1.7-42 *Periplaneta* - Alimentary canal

(30) A stomodaeal valve is present between gizzard and mesenteron.

(31) Hindgut (proctodaeum) comprises ileum, colon and rectum. The wall of rectum is provided with six rectal papillae, which help in the absorption of water and salts

(32) At the junction of foregut and midgut seven or eight finger like structure are present called hepatic caecae

(33) Cockroach is omnivorous, feeds on all sorts of organic debris. The digestive enzymes of saliva are mainly zymase and amylase. Most of the nutrients of food are digested in the crop. Digested food is absorbed in the mesenteron and hepatic caecae.

(34) Circulatory system in cockroach is of open type or lacunar type. In this type blood is always in direct contact with tissues. The blood flow through haemocoelic system.

(35) The heart is situated in pericardial sinus over the dorsal diaphragm.

(36) Heart of cockroach is neurogenic and longitudinally beaded with 13 chambers perforated by ostia having valves.

(37) The blood circulation is maintained by 13 pairs of wing-shaped involuntary alary muscles.

(38) Blood (or haemolymph) is colourless due to the absence of respiratory pigment. Hence it does not take part in respiration. Blood is composed of plasma and colourless blood cells called haemocytes.

(39) In cockroach oxygen is carried to individual cell without participation of blood. All body tissue receive oxygen directly.

(40) Respiratory system of cockroach consists of tracheal system. The tracheal system opens outside by ten pairs of spiracles (two pairs thoracic and eight pairs of abdominal). The spiracles are with valves.

(41) The first thoracic and first abdominal spiracles remain open all the times. The trachea is lined with spiral thickening of cuticle called intima which prevents the tracheal tubes from collapsing.

(42) Excretory organs of cockroach are Malpighian tubules which open at the junction of midgut and hindgut (ileum).

(43) Malpighian tubules absorb excretory substances from haemolymph and fat bodies and pass into the proctodaeum.

(44) In cockroach chief excretory product is uric acid (uricotelism).

(45) Fat body of cockroach contains mainly four types of cells, viz., trophocytes, mycetocytes, oenocytes and urate cells. The fat body is functionally analogous to liver of vertebrates. Mycetocytes contain symbiotic bacteria which help in synthesis of some amino acids, vitamins and of glycogen from glucose.

(46) Nervous system of cockroach consists of a nerve ring (in the head) and a double ventral nerve cord. The total number of ganglia in ventral nerve cord of cockroach is nine (Three thoracic and six abdominal).

(47) Sense organs in cockroach are – Photoreceptors (compound and simple eyes), thigmoreceptors (antennae), chemoreceptors (on maxillary and labial palps, labium and hypopharynx) and auditory receptors on anal cerci.

(48) Each compound eye is made up of about 2000 functional units called ommatidia.

(49) Each ommatidium is composed of a cuticular lens, two corneagen cells, a crystalline cone surrounded by four cone cells, a rhabdome surrounded by seven reticular cells and a basement membrane

(50) There are two types of vision in insects, mosaic vision or apposition image during day time and superposition or dull image in dim light.

(51) The vision in cockroach is called mosaic vision because in cockroach, pigment sheath of ommatidia is non-contractile so capable of only mosaic vision even during night.

(52) Simple eye of cockroach is mainly concerned with light collecting rather than image forming.

(53) In cockroach the endocrine organs are cardiac, corpora allata and prothoracic glands.

(54) Corpora cardica and corpora allata are attached to the brain. Corpora allata is neurosecretory and secretes juvenile hormone or neotinin.

(55) Intercerebral glands in brain secrete the brain hormone. Brain hormone stimulates the prothoracic glands to secrete a moulting hormone called ecdysone.

(56) In cockroach, sexes are separate, so dioecious or unisexual animal.

(57) Male organs consist of testes, vasa deferentia, ejaculatory duct, mushroom or utricular gland, phallic or conglobate gland and male gonapophysis.

(58) Testes of cockroach are located in the abdominal segments 4, 5 and 6. They produce sperms.

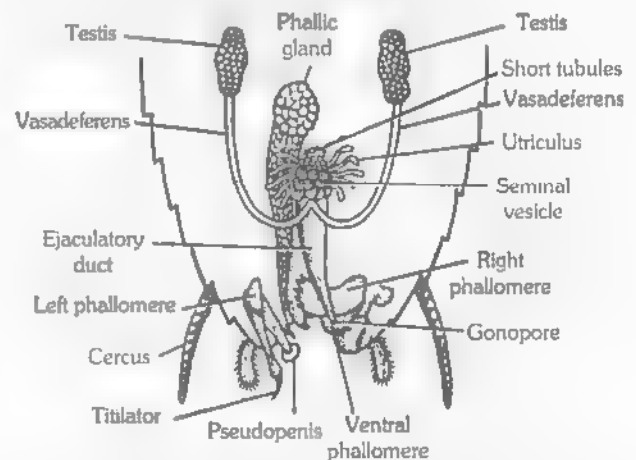


Fig : 1.7-43 *Periplaneta* - Male reproductive organs

(59) All sperms of a seminal vesicle are glued together into a large bundle called spermatophore. Spermatophore has three-layered wall. Inner layer secreted by utriculi majores; middle layer secreted by ejaculatory duct and outer layer secreted by phallic gland.

(60) There are three asymmetrical chitinous structures called male gonapophyses or phallomeres. Right phallomere has serrated edges and a hook; left phallomere has an asperate lobe, pseudopenis and a hooked titillator and ventral phallomere is simple.

(61) Female organs consist of ovaries, oviducts, vagina, genital chamber, spermathecae, colleterial glands and female gonapophysis (ovipositor processes). Ovaries of cockroach are located in the abdominal segments 2 to 6. Each ovary is made up of eight ovarioles.

(62) Oviducts fuse to form a common oviduct or vagina. It opens into gynatrium. Gynatrium opens out through female gonopore.

(63) Collateral glands open into gynatrium through a common pore. Left collateral gland secretes HCl and scleroprotein and right gland secretes hydroxy phenol. Ootheca of cockroach is formed of a protein secreted by collateral glands.

(64) A pair of spermathecae (left larger pyriform sac) are present near female genital pore. They store spermatophores received during copulation.

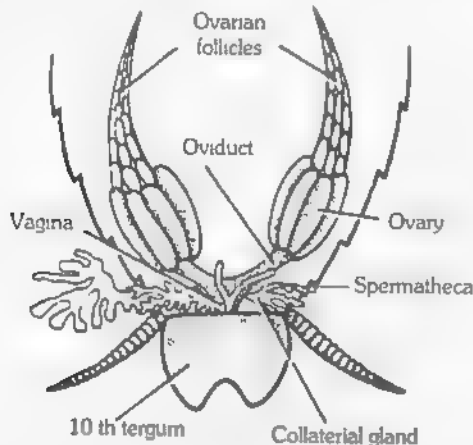


Fig : 1.7-44 Cockroach -Female reproductive organs

(65) Near the female gonopore three pairs of gonapophyses are present. They are helpful in copulation and in oviposition.

(66) Ootheca of cockroach contains 16 fertilized eggs in two rows (8 + 8). The egg of cockroach is centrolecithal type.

(67) Nymph of cockroach emerges out from ootheca.

(68) Metamorphosis in cockroach is incomplete or paurometabolous type. Metamorphosis is regulated by two hormones, ecdysone secreted by prothoracic glands and juvenile hormone secreted by corpora allata.

### Mosquito (*Anopheles*)

(1) Mosquito are inhabitants of damp and marshy places.

(2) The common genera of mosquito are –

*Culex* (body held parallel to surface while sitting),

*Aedes* (= *Stegomyia*) (body held parallel to surface while sitting, with black and white striped body),

*Anopheles* (Body held at an angle to the surface, dark spotted wing).

(3) The body of mosquito is divided into head, thorax and abdomen. Head bears a pair of antennae, compound eyes and mouth parts.

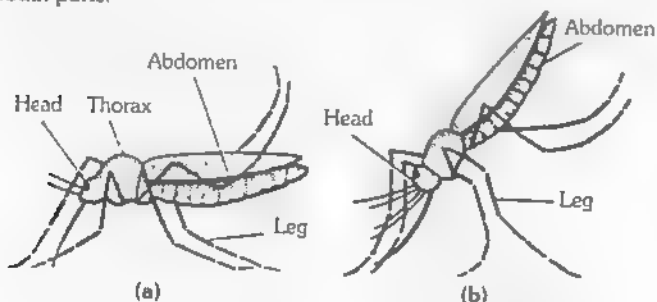


Fig : 1.7-45 Mosquitoes (a) *Culex* (b) *Anopheles*

(4) In adult mosquito, ocelli (simple eyes) are totally absent (in cockroach and housefly, ocelli are present).

(5) Thorax is three-segmented with only one pair of wings (mesothoracic). Metathoracic wings are modified into halteres which are balancing and sound producing structures.

(6) Mosquito shows sexual dimorphism. Sex differentiation can be done on the basis of antennae and maxillary palps. Antenna of a male mosquito is plumose (more hairy or brushy) and female is pilose (with few short hairs).

(7) Female mosquitoes are blood suckers. They have piercing and sucking mouthparts. Males feed on nectar and have only sucking mouthparts.

(8) Mouthparts found in both sexes are – Labrum, epipharynx forming upper lip and labium and proboscis.

(9) The puncturing elements in the mouthparts of female mosquito are maxillae and mandibles.

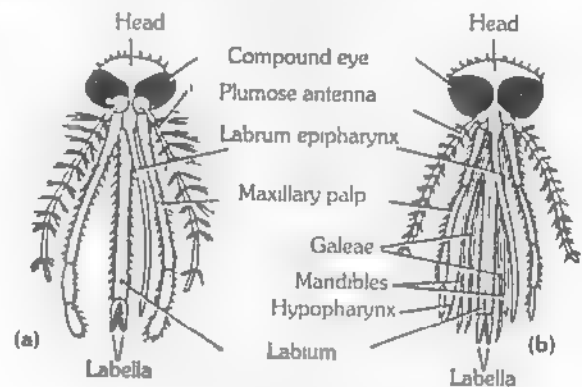


Fig : 1.7-46 *Anopheles* head and mouth parts  
(a) Male (b) Female

(10) Mandible are totally absent in male mosquito.

(11) Male and female mosquito copulate while in flight. The eggs are laid by the female in clusters on stagnant water of ponds, ditches, tanks, pools marshy places etc. The eggs develop and from each egg a small transparent larva called wriggler comes out into the water.

(12) Wiggler is a free swimming, active and aquatic larva performing wriggling movements. The body has head, thorax (without legs) and abdomen (9-segmented). Head bears a pair of compound eyes, a pair of simple eyes (absent in adult mosquito), a pair of small antennae.

(13) Wiggler has a lifespan of 3-4 days. During this period it undergoes four moults to give rise to five instar larva.

(14) 5<sup>th</sup> instar larva changes into a pupa (nonfeeding), it is comma-shaped. The pupa of mosquito is known as tumbler. It has a pair of respiratory trumpets.

(15) After completion of metamorphosis (complete metamorphosis), it will transform into an adult called 'Imago'.

(16) Johnston's organ lies in the second segment of antennae. In male mosquito, it helps to locate females by flight tone.

(17) Spraying of oil on stagnant water controls malaria because mosquito larvae cannot breathe and die.

(18) Fish which can be used in biological control of mosquitoes is *Gambusia*.

### Housefly (*Musca domestica*)

(1) Housefly belong to the class insecta of the phylum Arthropoda. *Musca domestica* is the most common housefly in Europe and America. The common Indian species in *musca nebulosa*.

(2) The body of housefly is divided into head, thorax and abdomen.

(3) Head is large with a pair of compound eyes, each made up about 4000 ommatidia, three ocelli and two antennae.

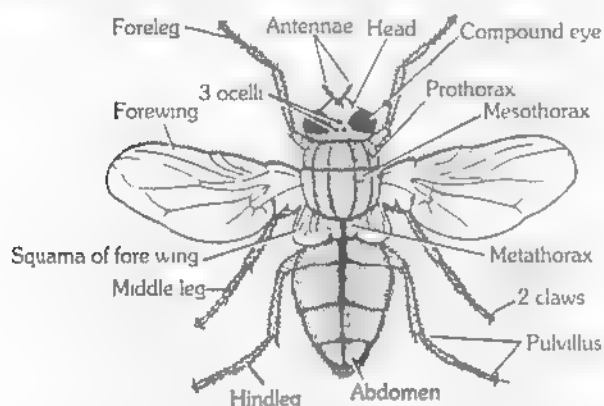


Fig : 1.7-47 *Musca domestica*

(4) Thorax is three segmented with three pairs of legs, one pair of wings (mesothoracic) and a pair of halteres. The halteres are present on metathorax and they are balancing organs during flight and also receive sound stimuli

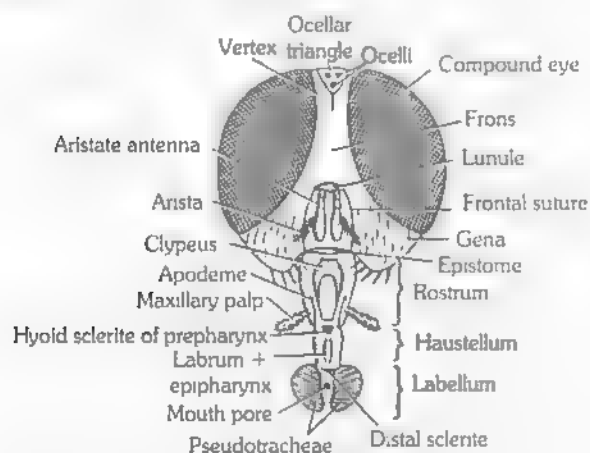


Fig : 1.7-48 Housefly-Head and mouth parts in frontal view

(5) Housefly differs from mosquito in having hindlegs resting on surface while sitting.

(6) The mouth parts of the common housefly are sponging type which are adapted for sucking liquid or semiliquid

(7) Labium is the most developed part of mouthparts forming the proboscis. The proboscis consists of three region – Rostrum, Haustellum, Labellum.

(8) Oral groove is found on haustellum containing blade-like hypopharynx and flattened labrum and epipharynx.

(9) Pseudotracheae are found in labellum.

(10) In the mouth parts of housefly, mandibles are totally absent

(11) House flies are saprophagous, feed upon all sorts of dead organic matter.

(12) The breeding season of housefly lasts from march to october (summer and rainy season).

(13) Housefly lays eggs on decaying organic matter such as cow dung, horse manure, human faeces etc.

(14) A larval stage occurs in housefly that lives in dung and is called maggot. This larva undergoes moulting twice. The period in between two moults is known as stadium while the form of larva are called instar. Thus there are two moults and three instars.

(15) The first instar has only one pair of posterior abdominal spiracles. So it is metapneustic.

(16) The second instar larva of housefly has one pair of abdominal and one pair of prothoracic spiracles. So it is amphipneustic.

(17) Different stages in the life history of housefly are – Egg → Larva (maggot) → pupa → Imago (adult).

(18) Larva of housefly respire by means of tracheae.

(19) An imago (young one of housefly) will come out after 4-5 days.

(20) Housefly shows a complete metamorphosis (holometabolous type).

Table : 1.7-7 Common Names

<i>Limulus</i>	–	King crab
<i>Palamnaeus</i>	–	Scorpion
<i>Lycosa</i>	–	Spider
<i>Astacus</i>	–	Crayfish
<i>Daphnia</i>	–	Waterflea
<i>Palaemon</i>	–	Freshwater prawn
<i>Palinurus</i>	–	Lobster
<i>Lucifer</i>	–	Shrimp
<i>Carcinus</i>	–	Crab
<i>Eupagurus</i>	–	Hermit crab
<i>Balanus</i>	–	Rock barnacle
<i>Julus</i>	–	Millipede
<i>Scolopendra</i>	–	Centipede
<i>Lepisma</i>	–	Silverfish
<i>Carasius</i>	–	Stick insect
<i>Phyllium</i>	–	Leaf insect
<i>Pediculus</i>	–	Louse
<i>Cimex</i>	–	Bedbug
<i>Xenopsylla</i>	–	Rat flea
<i>Drasophila</i>	–	Fruitfly
<i>Musca</i>	–	Housefly
<i>Phlebotomus</i>	–	Sandfly
<i>Glossina</i>	–	Tick fly
<i>Bombyx</i>	–	Silkworm

## Phylum Mollusca – The soft bodied animals

(L., *Mollis* or *Molluscus* = Soft bodied)

**Brief History :** Aristotle described a number of molluscs. Johnston (1650) proposed the name of the phylum.

### General characters

- (1) Molluscs are multicellular organisms.
- (2) They are mostly marine.
- (3) They have a bilateral symmetry, but snails are asymmetrical.
- (4) They are triploblastic animals.
- (5) They are coelomate animals. True coelom is reduced and haemocoel is well developed in them.
- (6) They have organ system grade of organization.
- (7) The body is soft and unsegmented.
- (8) The soft body is covered by a fleshy fold of the body wall. It is called mantle.
- (9) The molluscs are provided with one or two calcareous shells. The shells may be external or internal, univalve or bivalve.
- (10) Respiration is carried out by the gills or pulmonary chambers.
- (11) The digestive system is well developed. It contains a radula and a hepatopancreas.
- (12) The circulatory system is of an open type. Blood with amoebocytes, respiratory pigment is copper containing haemocyanin dissolved in plasma.
- (13) The excretory organ is the kidney (organ of Bojanus).
- (14) The nervous system is well developed with paired ganglia, commissures and connectives
- (15) The sensory organs are eyes, statocysts and osphradia (a chemoreceptor to test chemical nature of water).
- (16) Reproduction is sexual. Sexes are separate in them, or they are hermaphrodites.
- (17) The development in their case is either direct or indirect with free larval forms like trochophore, veliger, glochidium, etc.

**Classification of Mollusca :** On the basis of body shape and symmetry and characteristics of foot mantle, respiratory organs, nervous system, etc. phylum mollusca are divided into seven classes :

### Class 1. Monoplacophora

- (1) The body is bilaterally symmetrical and segmented.
- (2) The shell is formed of a single valve.
- (3) The head is without eyes and tentacles
- (4) The gills are external and serially arranged.
- (5) The nephridia are five pairs.

Example : *Neopilina galathea*

□ *Neopilina* is a living fossil and connecting link between Annelida and Mollusca.

### Class 2. Aplacophora or Solenogasters

- (1) The body is worm-like, bilaterally symmetrical and cylindrical
  - (2) The head, mantle, foot, shell and nephridia are absent.
  - (3) The body is covered with spicule-bearing cuticle.
  - (4) The digestive tract is straight with radula.
  - (5) A mid dorsal longitudinal keel or crest is often present .
- Example : *Neomenia*, *Chaetoderma*, etc.,

### Class 3. Polyplacophora

- (1) These molluscs are bilaterally symmetrical, and dorsoventrally flattened.
- (2) Head small, without eyes and tentacles
- (3) The shell is composed of a longitudinal series of 8 plates.
- (4) The foot is flat and ventral.
- (5) The radula is well developed.
- (6) Respiration by 8 to 60 pairs of gills.

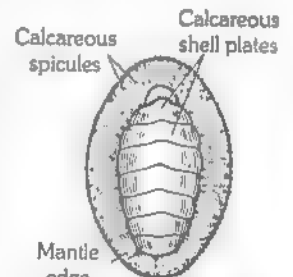


Fig : 1.7-49 Chiton

- (7) Unisexual; only one gonad; trochophore larval stage.

Example : *Chiton*, *Cryptochiton*, etc.

□ On the dorsal surface of chiton is a convex shell composed of 8 transversely elongated calcareous plates arranged in a longitudinal manner.

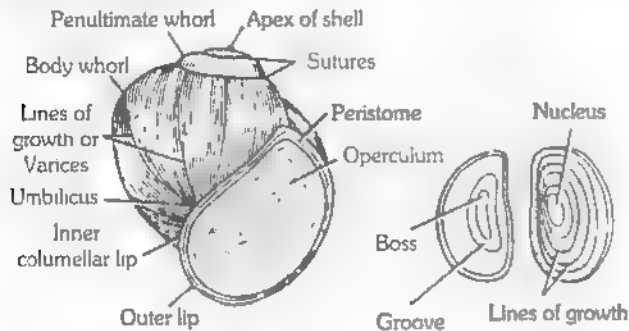
### Class 4. Gastropoda

- (1) It is the largest class of Mollusca.
- (2) It seems that these animals are moving on their stomach, hence the name gastropoda.
- (3) Gastropods are marine, fresh water or terrestrial animals. A few are parasitic
- (4) The body is unsegmented and asymmetrical.
- (5) The shell is univalve and spirally coiled due to torsion.
- (6) The head is distinct. It bears tentacles, eyes and a mouth.
- (7) The foot is ventral and muscular.
- (8) The buccal cavity is provided with a radula.
- (9) The circulatory system is open.
- (10) Respiratory organs are gills (ctinidia), or pulmonary sac or both.
- (11) Nervous system usually with four pairs of ganglia.
- (12) The sexes are mostly separate, while some forms are hermaphrodite.
- (13) The development includes veliger and trochophore larvae.

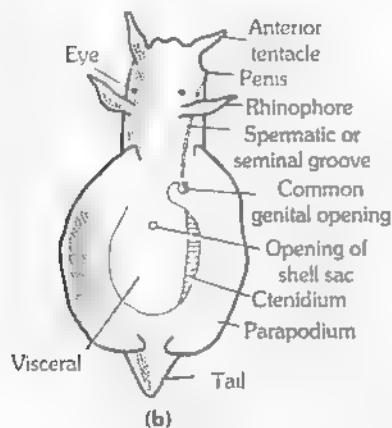
Examples : *Haliotis*, *Cypraea*, *Pila*, *Murex*, *Aplysea*, *Doris*, *Limax*, *Patella*, etc.

□ *Limax* is a terrestrial gastropod. It creeps on a self-secreted tract.

□ *Doris* is a marine gastropod, commonly called true limpet. It has an aspidobranch gill.



(a)



(b)

Fig : 1.7-50 (a) *Pila globosa* (b) *Aplysia*

#### Class 5. Scaphopoda

- (1) It is the small group of marine molluscs.
- (2) The foot is boat-shaped.
- (3) The eyes, the tentacles and ctenidia are absent.
- (4) Marine, bilaterally symmetrical molluscs.

Examples : *Siphonodentalium*, *Dentalium*, and *Pulsellum*

□ *Dentalium* is commonly called tusk shells

#### Class 6. Pelecypoda or Bivalvia or Lamellibranchiata

- (1) Pelecypoda are aquatic in habit.
- (2) The body is bilaterally symmetrical and laterally compressed
- (3) The shell is formed of two distinctive shell plates.
- (4) The head is not distinct.
- (5) The alimentary canal shows a crystalline style.
- (6) The gills, excretory organs and the other structures are paired.



Fig : 1.7-51 *Dentalium*

(7) The sexes are separate or united

(8) The development is indirect having a glochidium larva.

Example : *Mytilus*, *Unio*, *Teredo*, *Lamellidens*, *Solen*, *Pecten*, *Pinctada*, etc

□ *Teredo* bores through wood of ship but is without segmentation.

□ Pearl oysters belongs to the class pelecypoda.

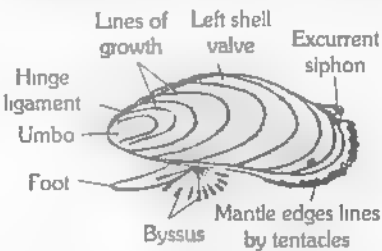


Fig : 1.7-52 *Mytilus*

#### Class 7. Cephalopoda or Siphonopoda

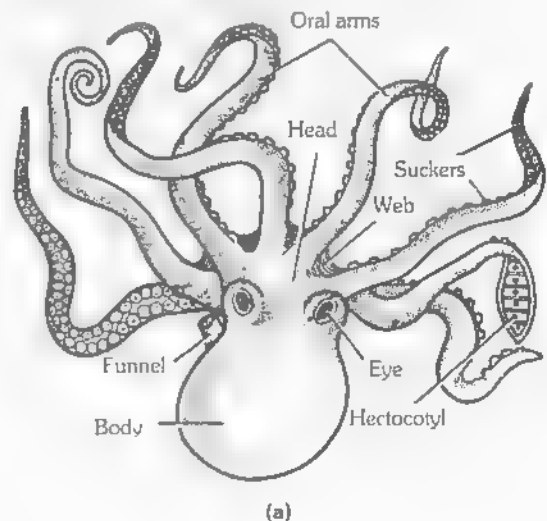
- (1) Most developed, marine and actively swimming by ejecting jets of water through exhalant siphon of mantle.
- (2) The body is bilaterally symmetrical.
- (3) The foot is modified into arms and funnel.
- (4) The shell may be either absent or rudimentary; it may be internal or external.
- (5) Nervous system is highly developed.
- (6) The odontophore with a radula is present.
- (7) The ink-gland is present.
- (8) The sexes are separate
- (9) The development is direct hence no metamorphosis and larval stage.

Example : *Nautilus*, *Loligo*, *Sepia*, *Octopus*, etc.

□ *Nautilus* has an external coiled and chambered shell

□ *Octopus* has good learning power and can be trained.

□ Members of genus *Architeuth* are known as giant squid and are largest living invertebrates.



(a)

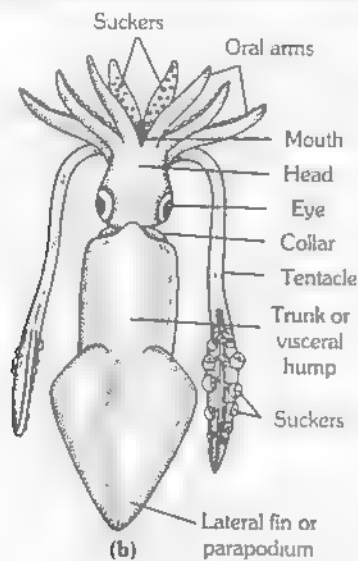
Fig : 1.7-53 (a) *Octopus* (b) *Sepia*

Table : 1.7-8 Common Names

<i>Chiton</i>	-	Sea mica (Mail shell)
<i>Dentalium</i>	-	Tusk shell
<i>Patella</i>	-	Limpet
<i>Fissurella</i>	-	Key-hole limpet
<i>Trochus</i>	-	Top shell
<i>Pila</i>	-	Apple snail
<i>Crepidula</i>	-	Slipper shell
<i>Cypraea</i>	-	Cowrie
<i>Natica</i>	-	Star shell
<i>Buccinum</i>	-	Whelk
<i>Doris</i>	-	Sea lemon
<i>Aplysia</i>	-	Sea hare
<i>Turbo</i>	-	Cat's eyes
<i>Vermetes</i>	-	Worm shell
<i>Nassa</i>	-	Mud shell
<i>Conus</i>	-	Cone shell
<i>Bulla</i>	-	Bubble shell
<i>Helix</i>	-	Land snail
<i>Limax</i>	-	Slug
<i>Pteropod</i>	-	Sea butterfly
<i>Unio</i>	-	Freshwater mussel
<i>Mytilus</i>	-	Sea mussel
<i>Spandylus</i>	-	Edible oyster
<i>Pinctada</i>	-	Pearl oyster
<i>Pecten</i>	-	Scallop
<i>Teredo</i>	-	Shipworm
<i>Solen</i>	-	Razor clam
<i>Sepia</i>	-	Cuttlefish
<i>Loligo</i>	-	Squid (sea arrow)
<i>Octopus</i>	-	Devilfish
<i>Spirula</i>	-	Spiral shell
<i>Architeuthis</i>	-	Giant squid

## Phylum Echinodermata – The spiny skinned animals

(Gk. *echinos* = spines; *derma* = skin/covering)

**Brief History :** Although Jacob Klein (1738) had earlier coined the name "Echinodermata", yet Linnaeus included these animals under "Mollusca", and Lamarck under his class "Radiata" as "Echinodermes". Finally, Leuckart (1847) raised the group to the status of a separate phylum.

### General characters

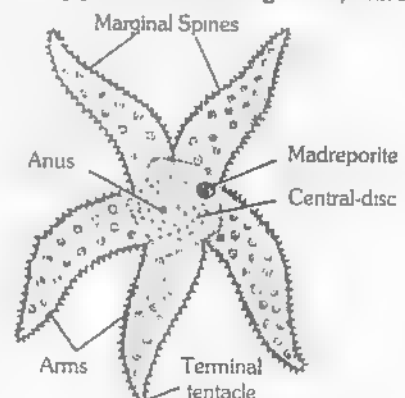
- (1) Echinoderms are exclusively marine beings.
- (2) They are triploblastic and coelomate (enterocoelomate) animals.
- (3) They have radially symmetrical body. The radial symmetry is due to sedentary or sessile mode of life and it is a secondary character in echinoderms.
- (4) They have organ system grade of organization.
- (5) They have well developed endoskeleton formed of calcareous ossicles and spines.
- (6) They have a water-vascular system (Ambulacral system) with tube-feet for locomotion, feeding and respiration.
- (7) Circulatory system is of the open-type.
- (8) Respiratory organs include dermal branchiae, tube feet, respiratory tree and bursae
- (9) Nervous system is complex and contains both central and peripheral components, but no brain.
- (10) The sensory organs are poorly developed.
- (11) The excretory organs are absent.
- (12) They have pedicellariae.
- (13) Development is indirect.
- (14) The larval forms are bilaterally symmetrical.
- (15) Regeneration power is well developed in Echinoderms.

**Classification of Echinodermata :** On the basis of body shape, position of madreporite and kind of larval form, echinoderms are classified into two subphylum.

**Subphylum (I) Eleutherozoa :** Free-living echinoderms with ventral mouth.

### Class 1. Asteroidea

- (1) Starfishes or sea stars.
- (2) Arms 5 or more and not sharply marked off from the central disc.
- (3) Tube feet in orally placed ambulacral grooves; with suckers.

Fig : 1.7-54 *Asteroidea* (Sea star)

(4) Anus and madreporite aboral.

(5) Pedicellariae present.

(6) Free-living, slow-creeping, predaceous and scavengerous.

Examples : *Astropecten*, *Luidia*, *Goniaster*, *Oreaster* (= *Pentaceros*), *Asterina*, *Solaster*, *Pteraster*, *Echinaster*, *Asterias*, *Heliaster*, etc.

### Class 2. Ophiuroidea

(1) Brittle-stars and allies.

(2) Body star-like with arms sharply marked off from the central disc.

(3) Pedicellariae absent.

(4) Stomach sac-like; no anus.

(5) Ambulacral grooves absent or covered by ossicles; tube feet without suckers.

(6) Madreporite oral

Examples : *Ophiura*, *Ophiothrix*, *Ophioderma*, *Ophiopholis*, *Gorgonocephalus*, *Asteronyx*.

### Class 3. Echinoidea

(1) Body not divided into arms; globular (sea urchins), or flattened disc-like (sea-cakes).

(2) Mouth at lower pole, covered by 5 strong and sharp teeth, forming a biting and chewing apparatus called "Aristotle's Lantern".

(3) Tube-feet slender with suckers.

(4) Skin ossicles fused to form a rigid globular, disc like, or heart-shaped shell or test with movable spines.

(5) 3-jawed pedicellariae present in skin.

(6) Gut long, cylindrical and coiled. Anus present.

(7) Larval forms pluteus and Echinopluteus.

Examples : *Echinus*, *Clypeaster*, *Echinarachinus*, *Echinocardium*, etc.

□ Members of Echinoidea are also known as Floating stone.

### Class 4. Holothuroidea

(1) Body massive, long and cylindrical like a cucumber; elongated in oral-aboral axis; no arms.

(2) Mouth at anterior and anus at posterior ends.

(3) Mouth surrounded by many hollow retractile tentacles.

(4) Tube feet usually present; sucker-like.

(5) Skin leathery, but relatively soft, without spines or pedicellariae; may have an endoskeleton of minute calcareous ossicles.

(6) Respiration and excretion by two long and highly branched tubes (= respiratory tree) extending into coelom from cloaca.

(7) Larval form Auricularia

Examples – *Holothurta*, *Cucumaria* etc

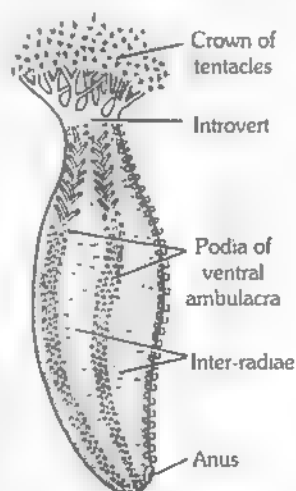


Fig : 1.7-55 *Holothurta*

**Subphylum (II) Pelmatozoa** : Stalked, sedentary echinoderms, with mouth situated on upper side.

### Class 1. Crinoidea

(1) Body flattened and pentamerous; distinguished into a small and circular central disc and five or more (in multiples of five) long, then, branched and flexible arms radiating from the disc.

(2) Disc enclosed in a hard, cup-shaped calyx formed of calcareous plates; calyx attached to a substratum by a stalk or simply by its aboral surface.

(3) Mouth in middle and anus excentral upon a cone, both upon oral surface. 5 ambulacral grooves run from mouth upto the tips of the arms.

(4) Tube feet sucker-like; restricted to central disc; can help in food-collection.

(5) Some forms (sea-lilies) permanently sessile and attached to sea-bottom by a long stalk; others (feather stars) free-swimming, but have flexible cirri for gripping objects in water.

(6) Spines and pedicellariae absent in skin.

Examples : *Antedon*, *Neometra*, etc.

Table : 1.7-9 Common Names

<i>Asterias</i>	–	Starfish
<i>Astropecten</i>	–	Starfish
<i>Pentaceros</i>	–	Sea pentagon
<i>Ophiothrix</i>	–	Brittle star
<i>Gorgonocephalus</i>	–	Basket star
<i>Echinus</i>	–	Sea urchin
<i>Echinocardium</i>	–	Heart urchin
<i>Clypeaster</i>	–	Sand dollar
<i>Cucumaria</i>	–	Sea cucumber
<i>Antedon</i>	–	Feather star

## Phylum Chordata

### General Characters

(1) Aquatic, aerial or terrestrial. All free-living with no fully parasitic forms.

(2) Body small to large, bilaterally symmetrical and metamerically segmented.

(3) A post anal tail usually projects beyond the anus at some stage and may or may not persist in the adult.

(4) Exoskeleton often present; well developed in most vertebrates

(5) Body wall triploblastic with 3 germinal layers : ectoderm, mesoderm and endoderm.

(6) Coelomate animals having a true coelom, enterocoelic or schizocoelic in origin.

(7) A skeletal rod, the notochord, present at some stage in life cycle.

(8) A cartilaginous or bony, living and jointed endoskeleton present in the majority of members (vertebrates).



(9) Pharyngeal gill slits present at some stage; may or may not be functional.

(10) Digestive system complete with digestive glands.

(11) Blood vascular system closed. Heart ventral with dorsal and ventral blood vessels. Hepatic portal system well developed.

(12) Excretory system comprising proto-or meso- or meta-nephric kidneys.

(13) Nerve cord dorsal and tubular. Anterior end usually enlarged to form brain.

(14) Sexes separate with rare exceptions.

**Classification of chordata** : Phylum chordata can be divided into two groups: Acrania (Protochordata) and Craniata (Euchordata) having contrasting characters.

**Group A. Acrania (Protochordata)** : (Gk. *a* = absent; *kranion* = head,) or, (Gk. *protos* = first; *chorde* = cord). All marine, small, Primitive or lower chordates. Lacking a head, a skull or cranium, a vertebral column, jaws and brain. About 2,000 species. The Acrania is divided into three subphyla: Hemichordata, Urochordata and Cephalochordata, chiefly on the character of notochord present.

**Subphylum I. Hemichordata** : (Gk. *hemi* = half; *chorde* = cord). Body divided into 3 regions: Proboscis, collar and trunk. Notochord doubtful, short, confined to proboscis and non-homologous with that of chordates.

**Class 1. Enteropneusta** : (Gk. *enteron* = gut; *pneustos* = breathed). Body large and worm-like. Gill slits numerous. Intestine straight. Acorn or tongue worms. 70 species. e.g. *Balanoglossus*, *Saccoglossus*

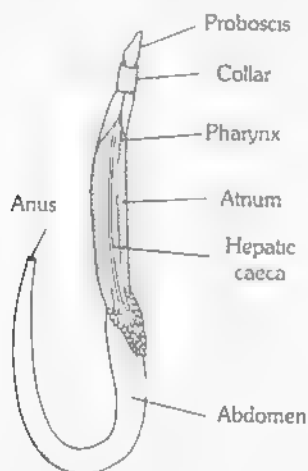


Fig : 1.7-56 *Balanoglossus*

**Class 2. Pterobranchia** : (Gk. *pteron* = feather; *branchion* = gill). Body small and compact. Gill-slits one pair or none. Intestine U-shaped. Pterobranchs. 20 species. e.g. *Cephalodiscus*, *Rhabdopleura*.

**Subphylum II. Urochordata or Tunicata** : (Gk. *oura* = a tail;) (L. *chorde* = cord). Notochord and nerve cord only in tadpole-like larva. Adult sac-like, often sessile and encased in a protective tunic. Tunicates.

**Class 1. Ascidiacea** : Sessile tunicates with scattered muscles in tunic. Solitary, colonial or compound. Gill-clefts numerous. Ascidians or sea squirts. 1,200 species. e.g. *Herdmania*, *Ciona*, *Molgula*.

❑ Retrogressive metamorphosis present in *Herdmania*.

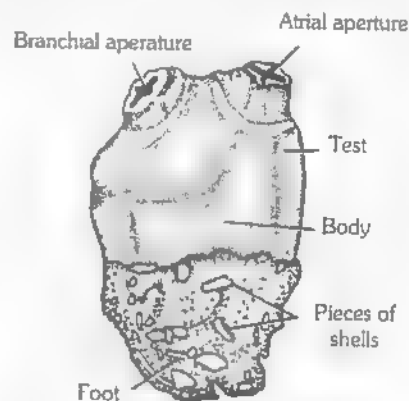


Fig : 1.7-57 *Herdmania* (Sea-squirt)

**Class 2. Thaliacea** : Free-swimming or pelagic tunicates with circular muscles in tunic. Sometimes colonial. Salps or chain tunicates. 30 species. *Salpa*, *Doliolum*, *Pyrosoma*.

**Subphylum III. Cephalochordata** : (Gk. *kephale* = head;) or (L. *chorde* = cord). Notochord and nerve cord present throughout life along entire length of body.

**Class Leptocardii** : Body fish-like, segmented with distinct myotomes and numerous gill-slits. Free swimming and burrowing. Lancelets. 30 species. e.g. *Branchiostoma* (= *Amphioxus*), *Asymmetron*.

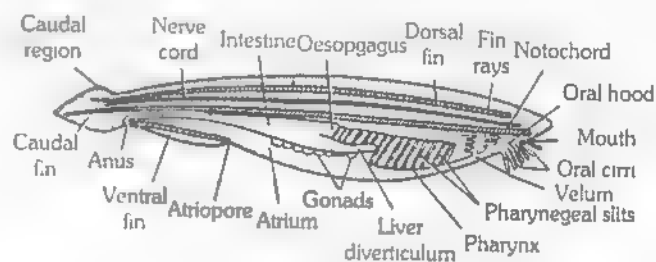


Fig : 1.7-58 *Amphioxus*

**Group B. Craniata (Euchordata)** : Aquatic or terrestrial, usually large-sized, higher chordates or vertebrates with distinct head. Notochord is embryonic, in adult replaced by vertebral column. Jaws and brain protected by a skull or cranium. The Craniata includes a single subphylum, the vertebrata.

**Subphylum IV. Vertebrata** : (L. *vertebratus* = backbone). Notochord supplemented or replaced by a vertebral column or backbone composed of overlapping vertebrae. Body divisible into head, neck, trunk and tail. Usually dioecious. Vertebrates, largest chordate subphylum including about 46,500 species. The subphylum Vertebrata is divided into two divisions: Agnatha and Gnathostomata, with contrasting characters as follows;

**Division I. Agnatha** : (Gk. *a*, not; *gnathos*, jaw). Jaw less primitive fish-like vertebrates without true jaws and paired limbs.

**Class 1. Ostracodermi.** (Gk. *ostrakon* = shell; *derma* = skin). Several extinct orders of ancient primitive heavily armoured, Palaeozoic, world's first vertebrates, collectively called the ostracoderms. e.g. *Cephalaspis*, *Drepanaspis*.

**Class 2. Cyclostomata.** (Gk. *cyklos* = circular; *stoma* = mouth). Body eel-shaped, without scales, jaws and lateral fins. Mouth rounded and suctorial. Gills 5–16 pairs. Parasites and scavengers, 45 species. e.g. Lampreys (*Petromyzon*) and hagfishes (*Myxine*).

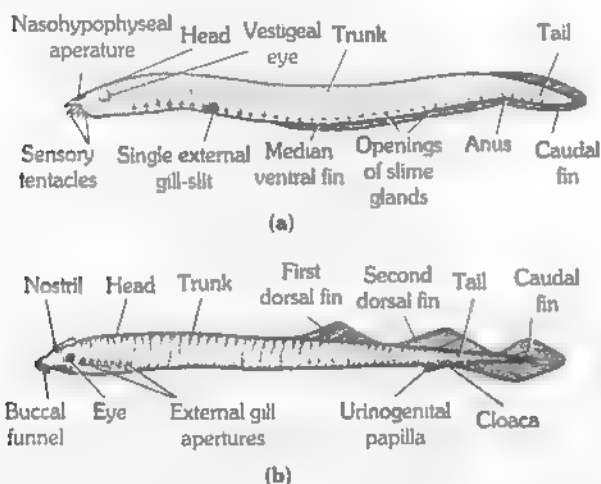


Fig : 1.7-59 (a) *Myxine* (b) *Petromyzon*

**Division II. Gnathostomata :** (Gk. *gnathos* = jaw; *stoma* = mouth). Jawed vertebrates having true jaws and paired limbs.

For convenience, some taxonomists further divide Gnathostomata division into two super classes. All the fishes like aquatic gnathostomes are placed in the superclass Pisces, whereas all the four-footed terrestrial gnathostomes in the superclass Tetrapoda. Their contrasting features are as follows:

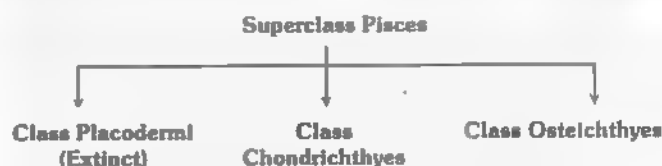
#### Superclass 1. Pisces

- (1) Exclusively aquatic gnathostome vertebrates.
- (2) Paired limbs, if present, as fins.
- (3) Median fins present
- (4) Skin usually moist and scaly
- (5) Respiration aquatic, by gills
- (6) Sense organs functional in water
- (7) It consist of fishes only.

#### Superclass 2. Tetrapoda

- (1) Aquatic or terrestrial. Some arboreal and aerial
- (2) Paired pentadactyle limbs present
- (3) Median fins absent
- (4) Skin usually dry and cornified
- (5) Respiration aerial, by lungs
- (6) Sense organs functional in air.
- (7) It consist of classes Amphibia, Reptilia, Aves and Mammals.

### Superclass Pisces



#### Class 1. Chondrichthyes (The Cartilaginous Fishes)

(Gk. *chondros* = cartilage; *ichthys* = fish)

##### General characters.

- (1) Mostly marine and predaceous.
- (2) Body fusiform or spindle shaped.
- (3) Fins both median and paired, all supported by fin rays. Pelvic fins bear claspers in male. Tail heterocercal.
- (4) Skin tough containing minute placoid scales and mucus glands.
- (5) Endoskeleton entirely cartilaginous, without true bones. Notochord persistent. Vertebrae complete and separate. Pectoral and pelvic girdles present.
- (6) Mouth ventral. Jaws present. Teeth are modified placoid scales. Stomach J-shaped. Intestine with spiral valve.
- (7) Respiration by 5 to 7 pairs of gills. Gill-slits separate and uncovered (except, *chimaeras*). Operculum absent. No air bladder and lungs.
- (8) Heart 2-chambered (1 auricle and 1 ventricle). Sinus venosus and conus arteriosus present. Both renal and portal systems present. Temperature variable (poikilothermous or cold blooded or ectothermal animal).
- (9) Kidneys mesonephric or opisthonephric. Excretion ureotelic. Cloaca present.

(10) Brain with large olfactory lobes and cerebellum. Cranial nerves 10 pairs.

(11) Olfactory sacs do not open into pharynx. Membranous labyrinth with 3 semicircular canals. Lateral line system present.

(12) Sexes separate. Gonads paired. Gonoducts open into cloaca. Fertilization internal. Oviparous or ovoviviparous. Eggs large, yolk. Cleavage meroblastic. Development direct, without metamorphosis

#### Classification of Chondrichthyes

##### (a) Subclass I. Selachii : (Gk., *selachos*, a shark)

- (1) Multiple gill slits on either side protected by individual skin flaps.
- (2) A spiracle behind each eye.
- (3) Cloaca present.

Examples : True sharks. Dogfishes (*Scoliodon*, *Chiloscyllium*, *Mustelus*, *Carcharinus*), spiny dogfish (*Squalus*) seven gilled shark (*Heptanchus*), *Stegastoma*, *Sphyrna*, *Rhineodon*. Skates and rays. Skate (*Raja*) Trygon, *Torpedo*, *Myliobatis*, *Rhinobatus*, *Pristis*.

□ Zebra shark (*Stegastoma*) is the most beautiful fish in the sea.

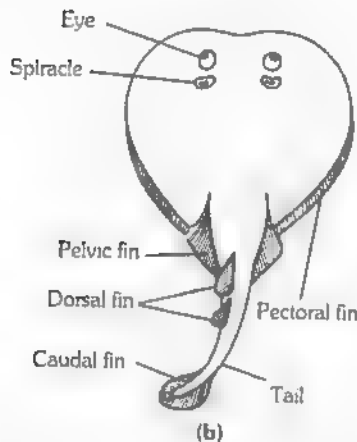
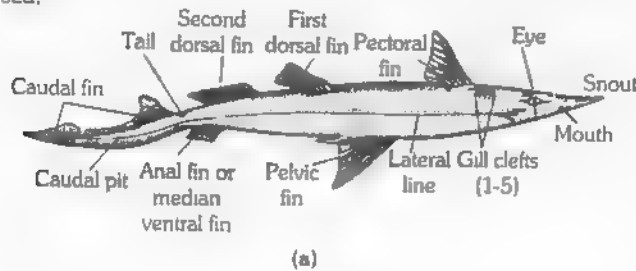


Fig : 1.7-60 (a) *Scoliodon* (b) *Torpedo*

(b) **Subclass II. Holocephali** : (Gk., halos, entire + kephale, head)

(1) Single gill opening on either side covered by a fleshy operculum.

(2) No spiracles, cloaca and scales.

(3) Jaws with tooth plates.

(4) Single nasal opening.

(5) Lateral line system with open groove. It serves to detect waves in water current.

Examples : *Hydrolagus* (= *Chimaera*).

**Class 2. Osteichthyes**—(The Bony fishes)

(Gk. osteon = bone; *ichthyes* = fish)

**General Characters**

(1) Inhabit all sorts of water-fresh, brackish or salt; warm or cold

(2) Body spindle-shaped and streamlined.

(3) Fins both median and paired, supported by fin rays of cartilage or bone. Tail usually homocercal.

(4) Skin with many mucus glands, usually with embedded dermal scales of 3 types; ganoid, cycloid or ctenoid. Some without scales. No placoid scales.

(5) Endoskeleton chiefly of bone. Cartilage in sturgeons and some other. Notochord replaced by distinct vertebrae Pelvic girdle usually small and simple or absent. Claspers absent.

(6) Mouth terminal or sub terminal. Jaws usually with teeth. Cloaca lacking, anus present.

(7) Respiration by 4 pairs of gill on body gill arches, covered by a common operculum on either side.

(8) An air (swim) bladder often present with or without duct connected to pharynx. Lung-like in some (Dipnoi).

(9) Ventral heart 2-chambered (1 auricle + 1 ventricle). Sinus venosus and conus arteriosus present. Aortic arches 4 pairs. Erythrocytes oval, nucleated. Temperature variable (poikilothermous).

(10) Adult kidneys mesonephric. Excretion ureotelic.

(11) Brain with very small olfactory lobes, small cerebrum and well developed optic lobes and cerebellum. Cranial nerves 10 pairs

(12) Well developed lateral line system. Internal ear with 3 semicircular canals

(13) Sexes separate. Gonads paired. Fertilization usually external. Mostly oviparous, rarely ovoviviparous or viviparous. Eggs minute to 12 mm. Cleavage meroblastic. Development direct, rarely with metamorphosis.

#### Classification of Osteichthyes

(a) **Subclass I. Sarcopterygii** : (Gk., sarcos = fleshy; pterygium = fin)

(1) Paired fins leg-like or lobed. With a fleshy, bony central axis covered by scales.

(2) Dorsal fins 2. Caudal fin heterocercal with an epichordal lobe.

(3) Olfactory sacs usually connected to mouth cavity by internal nostrils or choanae, hence the previous name of subclass, choanichthyes (Gk. *choana* = funnel; *ichthyes* = fish).

(4) Popularly called fleshy or lobe-finned, or air breathing fish. Divided into 2 superorders or orders: Crossopterygii and Dipnoi.

**Order 1. Crossopterygii** : (Gk. *crossoi* = a fringe; *pteryx* = fin)

(1) Paired fins lobate. Caudal fin 3-lobed.

(2) Premaxillae and maxillae present.

(3) Internal nares present or absent. Spiracles present.

(4) Air bladder vestigial.

Example : Primitive fleshy-finned extinct fishes. Single living genus *Latimeria*.

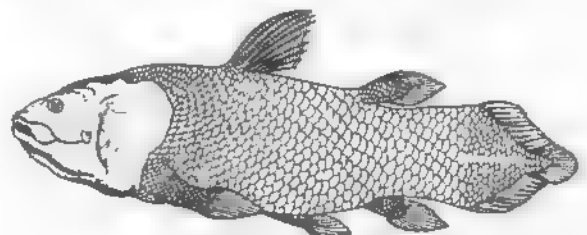


Fig : 1.7-61 *Latimeria*

Order 2. **Dipnoi** . (Gk. *di* = double ; *pnoe* = breathing)

- (1) Median fins continuous to form diphycercal tail.
- (2) Premaxillae and maxillae absent.
- (3) Internal nares present and spiracles absent.
- (4) Air bladder single or paired, lung-like

Examples : Lung fishes. Only 3 living genera : *Epiceratodus* (*Neoceratodus*), *Protopterus* and *Lepidosiren*

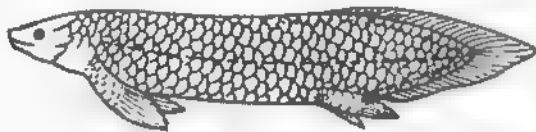


Fig : 1.7-62 *Neoceratodus*

(b) **Subclass II. Actinopterygii** : (Gr. *actis* = ray; *pteryx* = fin)

- (1) Paired fins thin, broad, without fleshy basal lobes, and supported by dermal fin rays.
- (2) One dorsal fin, may be divided.
- (3) Caudal fin without epichordal lobe.
- (4) Olfactory sacs not connected to mouth cavity.
- (5) Popularly called ray-finned fishes. Divided into 3 infraclasses or superorders: Chondrostei, Holostei and Teleostei.

Superorder A. **Chondrostei** : (Gk. *chondros* = cartilage ; *osteon* = bone)

- (1) Mouth opening large.
- (2) Scales usually ganoid.
- (3) Tail fin heterocercal.
- (4) Primitive ray-finned fish or cartilaginous ganoids.

Examples : *Acipenser* (Sturgeon), *Polyodon* (paddlefish)

Superorder B. **Holostei** : (Gk. *holos* = entire ; *osteon* = bone)

- (1) Mouth opening small.
- (2) Ganoid or cycloid scales.
- (3) Tail fin heterocercal.
- (4) Intermediate ray-finned fish, transitional between Chondrostei and Teleostei

Examples : *Lepisosteus* (garpike)

Superorder C. **Teleostei** – (Gk. *teleos* = complete; *osteon* = bone)

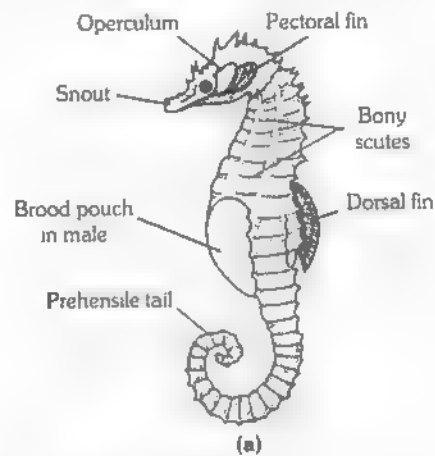
- (1) Mouth opening terminal, small.
- (2) Scales cycloid, ctenoid or absent.
- (3) Tail fin mostly homocercal.
- (4) A hydrostatic swim bladder usually present.
- (5) Advanced or modern ray-finned fishes

Examples – *Harpodon*, *Cyprinus*, *Labeo rohita*, *Catla*, *Betta*, *Carassius*, *Clarius*, *Heteropneustes* or *Saccobranchius*, *Wallago*, *Mystus*, *Electrophorus*, *Anguilla*, *Muraena* (moray) *Hemirhamphus*

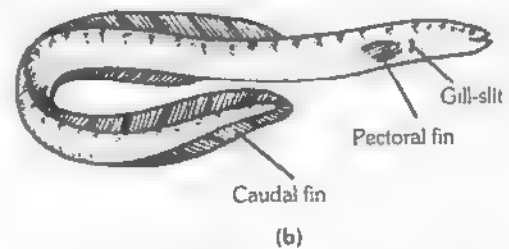
(half beak), *Belone* (garfish), *Hippocampus* (sea horse), *Syngnathus*, *Fistularia* *Ophiocephalus* or *channa* *Amphipneustes*, *Symbranchus*, *Mastacembelus*, *Macrogathus*, *Pterois*, *Pleuronectes*, *Synaptura*, *Solea*, *Echeneis* or *Remora*, *Tetrodon*

❑ *Hippocampus* (Sea horse) shows parental care. On the belly of male is a brood pouch for incubating eggs.

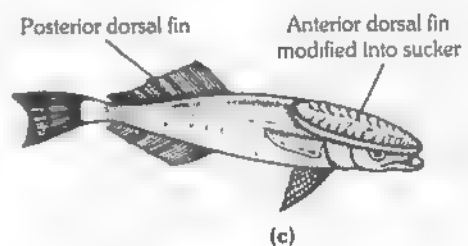
❑ *Remora* (*Echeneis*) has modified dorsal fin into a sucker. It attaches to the body of shark, whales, etc. (commensalism).



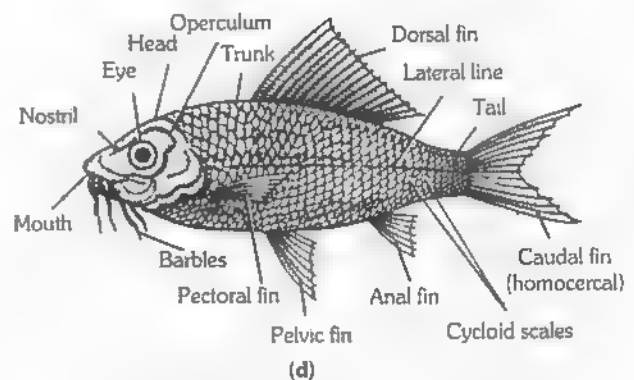
(a)



(b)



(c)



(d)

Fig. 1.7-63 : (a) *Hippocampus* (b) *Anguilla*  
(c) *Echeneis* (d) *Labeo*

Table : 1.7-10 Common Names

**Cartilaginous Fishes**

<i>Scoliodon</i>	-	Dogfish (Shark)
<i>Stegostoma</i>	-	Zebra shark (Tigerfish)
<i>Trygon</i>	-	Sting ray
<i>Torpedo</i>	-	Electric ray
<i>Rhinobatus</i>	-	Guitar fish
<i>Pristis</i>	-	Sawfish
<i>Chimaera</i>	-	Rat fish

**Bony Fishes**

<i>Clarius</i>	-	Catfish
<i>Echeneis</i>	-	Sucker fish
<i>Hippocampus</i>	-	Sea horse
<i>Gambusia</i>	-	Mosquito fish
<i>Exocoetus</i>	-	Flying fish
<i>Tetradon</i>	-	Globe fish
<i>Diodon</i>	-	Porcupine fish
<i>Cyanoglossus</i>	-	Flatfish
<i>Anabas</i>	-	Climbing fish
<i>Labeo rohita</i>	-	Indian carp
<i>Syngnathus</i>	-	Pipe fish
<i>Fistularia</i>	-	Flute fish
<i>Carassius</i>	-	Goldfish
<i>Anguilla</i>	-	Freshwater eel
<i>Oncorhynchus</i>	-	Pacific salmon

Table : 1.7-11 False Fishes

Common Names	Genus	Phylum
1. Jellyfish	<i>Aurelia</i>	Coelenterata
2. Silverfish	<i>Lepisma</i>	Arthropoda
3. Crayfish	<i>Astacus</i>	Arthropoda
4. Razorfish	<i>Solen</i>	Mollusca
5. Cuttlefish	<i>Sepia</i>	Mollusca
6. Devilfish	<i>Octopus</i>	Mollusca
7. Starfish	<i>Asterias</i>	Echinodermata
8. Hagfish	<i>Myxine</i>	Chordata

**Class Amphibia – The vertebrates with Dual life**(Gk. *Amphi* = both; *bios* = Life)**General characters**

- (1) Aquatic or semi aquatic (freshwater), air and water breathing, carnivorous, cold-blooded, oviparous, tetrapod vertebrates.
- (2) Head distinct, trunk elongated. Neck and tail may be present or absent.
- (3) Limbs usually 2 pairs (tetrapod), some limb less toes 4-5 (pentadactyle) or less. Paired fins absent. Median fins, if present, without fin rays.
- (4) Skin soft, moist and glandular. Pigment cells (chromatophores) present.
- (5) Exoskeleton absent. Digits claw less. Some with concealed dermal scales.

(6) Endoskeleton mostly bony. Notochord does not persist. Skull with 2 occipital condyles. i.e. Dicondylic skull.

(7) Mouth large. Upper or both jaws with small homodont teeth. Tongue often protrusible. Alimentary canal terminates into cloaca.

(8) Respiration by lungs, skin and mouth lining. Larvae with external gills which may persist in some aquatic adults.

(9) Heart 3-chambered (2 auricles + 1 ventricle). Sinus venosus present. Aortic arches 1-3 pairs. Renal and hepatic portal systems well developed. Erythrocytes large, oval and nucleated. Body temperature variable (poikilothermous).

(10) Kidneys mesonephric. Urinary bladder large. Urinary ducts open into cloaca. Excretion ureotelic.

(11) Brain poorly developed. Cranial nerves 10 pairs.

(12) Nostrils connected to buccal cavity. Middle ear with a single rod-like ossicle, columella. Larval forms and some aquatic adults with lateral line system.

(13) Sexes separate. Male without copulatory organ. Gonoducts open into cloaca. Fertilization mostly external. Females mostly oviparous.

(14) Development indirect. Cleavage holoblastic but unequal. No extra-embryonic membranes. Larva a tadpole which metamorphoses into adult.

**Classification of Amphibia :** The living amphibians belong to only 2,500 species, a very much smaller number than that of other principal classes of vertebrates. Ranging from mid-Palaeozoic (Devonian) to early Mesozoic (Triassic). They dominated the World during Carboniferous, but most of them have become extinct since long. The classification most generally followed nowadays was provided by G. Kingsley Noble (1924).

(a) **Subclass I. Stegocephalia (Extinct) :** Limbs pentadactyle. Skin with scales and bony plates. Skull with a solid bony roof leaving openings for eyes and nostrils. Permian to Triassic.



Fig : 1.7-64 Stegocephalia

**Order 1. Labyrinthodontia :** Oldest known tetrapods called stem Amphibia. Carboniferous to Triassic.

Example : *Eryops*.

**Order 2. Phyllospondyli** Small salamander-like. Carboniferous to permian

Example : *Branchiosaurs (Ichthyostega)*.

**Order 3. Lepospondyli** Small salamander or eel-like. Carboniferous to Permian.

Examples – *Diplocaulus*, *Lysorophus*.

(b) **Subclass II. Lissamphibia (living)** : Modern Amphibia lacking dermal bony skeleton. Teeth small, simple.

Order 1. **Gymnophiona or Apoda** : (Gk. gymnos = naked ; ophioneos = serpent-like)

(1) Limb less, blind, elongated worm like, burrowing tropical forms known as caecilians or blind worms.

(2) Tail short or absent, cloaca terminal.

(3) In some dermal scales embedded in skin which is transversely wrinkled.

(4) Skull compact, roofed with bone

(5) Limb girdle absent.

(6) Males have protrusible copulatory organs,

Examples *Ichthyophis*, *Uroaeoryphus*, *Rhinatrema*, *Typhlonectes*.

□ *Ichthyophis* is a Limb less amphibian showing parental care. It has no tongue.

Order 2. **Urodela or Caudata** : (Gk. Ura = tail ; delos = visible) or (L. = cauda = tail).

(1) Lizard-like amphibians with a distinct tail.

(2) Limbs 2 pairs, usually weak, almost equal.

(3) Skin devoid of scales and tympanum.

(4) Gills permanent or lost in adult.

(5) Males without copulatory organs.

(6) Larvae aquatic, adult-like, with teeth.

(7) It mainly includes Newts and Salamanders.

Examples : *Cryptobranchus*, *Megalobatrachus*, *Ambystoma*, *Salamandra*, *Desmognathus*, *Amphiuma*, *Plethodon*, *Siren*, *Pseudobranchius*, *Triturus*, *Necturus*.

□ Larva of *Ambystoma* is axolotl. It shows neoteny or paedogenesis.

□ The main difference between gymnophiona and urodela is that urodela have smooth moist skin.

Order 3. **Salientia or Anura** : (L., saliens = leaping ) or (Gk., an = without ; nura = tail)

(1) Specialized amphibia without tail in adults.

(2) Hind limbs usually adapted for leaping and swimming.

(3) Adults without gills or gill openings.

(4) Eyelids well-formed. Tympanum present.

(5) Skin loosely-fitting, scale less; mandible toothless.

(6) Pectoral girdle bony. Ribs absent or reduced. Vertebral column very small of 5-9 pre sacral vertebrae and a slender urostyle

(7) Fertilization always external.

(8) Fully metamorphosed without neotenic forms.

(9) It mainly includes frogs and toads.

Examples : *Alytes*, *Bombinator*, *Discoglossus*, *Pipa*, *Xenopus*, *Pelobates*, *Scaphiopus*, *Bufo*, *Rhinoderma*, *Dendrobates*, *Hyla*, *Gastrotheca*, *Rana*, *Polypedates* or *Rhacophorus*.

□ *Bufo* is a poisonous amphibian.

□ *Bombinator* is famous for warning colouration.

□ *Xenopus* is used as a test in diagnosis of human pregnancy.

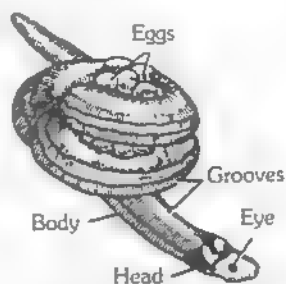


Fig : 1.7-65 *Ichthyophis*

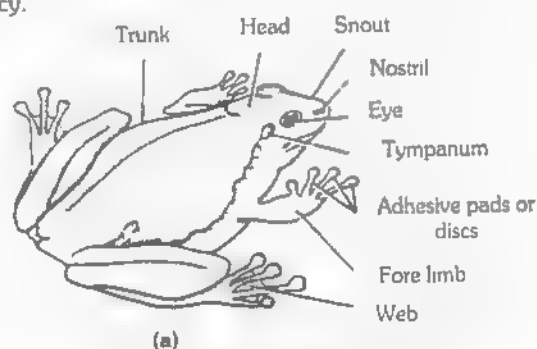


Fig : 1.7-67 (a) *Hyla* (b) *Alytes*

Table : 1.7-12 Common Names

<i>Uroaeoryphus</i>	-	Blindworm
<i>Ichthyophis</i>	-	Caecilian
<i>Ambystoma</i>	-	Tiger salamander
<i>Amphiuma</i>	-	Congo eel
<i>Cryptobranchus</i>	-	Hellbender
<i>Necturus</i>	-	Mud puppy
<i>Proteus</i>	-	Cave salamander
<i>Siren</i>	-	Mud eel
<i>Triton</i>	-	Newt
<i>Salamandra</i>	-	Salamander
<i>Rana tigrina</i>	-	Indian bull frog
<i>Alytes</i>	-	Midwife toad
<i>Bufo melanostictus</i>	-	Indian toad
<i>Pipa</i>	-	Surinam toad
<i>Hyla</i>	-	Tree frog
<i>Rhacophorus</i>	-	Flying frog
<i>Bombinator</i>	-	Fire bellied toad
<i>Xenopus laevis</i>	-	African clawed toad
<i>Ascaphus</i>	-	Bell toad
<i>Astylosternus</i>	-	Hairy frog
<i>Nototrema (Gastrotheca)</i>	-	Marsupial frog

## Class Reptilia –The creeping vertebrates

(L. reptare = to creep)

### General Characters

(1) Predominantly terrestrial, creeping or burrowing, mostly carnivorous, air-breathing, cold-blooded, oviparous and tetrapodal vertebrates.

(2) Body bilaterally symmetrical and divisible into 4 regions-head, neck, trunk and tail.

(3) Limbs 2 pairs, pentadactyle. Digits provided with horny claws. However, limbs absent in a few lizards and all snakes.

(4) Exoskeleton of horny epidermal scales, shields, plates and scutes

(5) Skin dry, cornified and devoid of glands.

(6) Mouth terminal. Jaws bear simple conical teeth. In turtles teeth replaced by horny beaks.

(7) Alimentary canal terminates into a cloacal aperture.

(8) Endoskeleton bony. Skull with one occipital condyle (monocondylar). A characteristic T-shaped inter clavicle present.

(9) Heart usually 3-chambered, 4-chambered in crocodiles. Sinus venosus reduced. 2 systemic arches present. Red blood corpuscles oval and nucleated. Cold-blooded.

(10) Respiration by lungs throughout life.

(11) Kidney metanephric. Excretion uricotelic.

(12) Brain with better development of cerebrum than in Amphibia. Cranial nerves 12 pairs.

(13) Lateral line system absent. Jacobson's organs present in the roof of mouth.

(14) Sexes separate. Male usually with a muscular copulatory organ.

(15) Fertilization internal. Mostly oviparous. Large yolky meroblastic eggs covered with leathery shells, always laid on land. Embryonic membranes (amnion, chorion, yolk sac and allantois) appear during development. No metamorphosis. Young resemble adults.

(16) Parental care usually absent

**Classification of Reptilia** : According to Bogert, there are more than 7,000 living and several extinct species of reptiles, grouped into approximately 16 orders of which only 4 are living.

(a) **Subclass I Anapsida** – Primitive reptiles with a solid skull roof. No temporal openings.

Order 1. **Chelonia or Testudinata** : (Gk. *chelone* = turtle) or (L. *testudo* = turtle)

(1) Body short, broad and oval.

(2) Limbs clawed and/or webbed, paddle-like.

(3) Body encased in a firm shell of dorsal carapace and ventral plastron, made of dermal bony plates. Thoracic vertebrae and ribs usually fused to carapace.

(4) Skull anapsid, with a single nasal opening and without a parietal Foramen. Quadrate is immovable.

(5) No sternum is found.

(6) Teeth absent. Jaws with horny sheaths.

(7) Cloacal aperture a longitudinal slit.

(8) Heart incompletely 4-chambered with a partly divided ventricle.

(9) Copulatory organ single and simple.

(10) About 400 species of marine turtles, freshwater terrapins and terrestrial tortoises.

Examples : *Chelone*, *Chrysemys*, *Testudo*, *Trionyx*, *Dermochelys*.

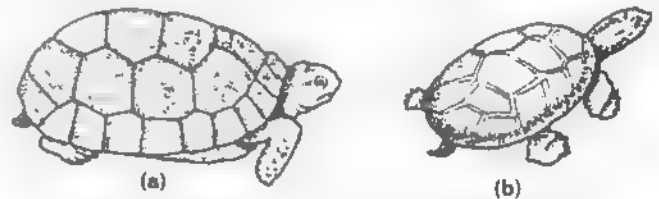


Fig : 1.7-68 (a) Giant tortoise, (b) Snake necked turtle

(b) **Subclass II Euryapsida (extinct)** : Skull with a single dorso-lateral temporal opening on either side bounded below by postorbital and squamosal bones.

(c) **Subclass III Parapsida (extinct)** : Skull with a single dorso-lateral temporal opening on either side bounded below by the supra temporal and post frontal bones.

(d) **Subclass IV Synapsida (extinct)** : Skull with a single lateral temporal opening on either side bounded above by the postorbital and squamosal bones.

(e) **Subclass V Diapsida (Living)** : Skull with two temporal openings on either side separated by the bar of postorbital and squamosal bones.

Order 2. **Rhynchocephalia** : (L. *rhynchos* = snout ; Gk. *kephale* = head)

(1) Body small, elongated, lizard-like.

(2) Skull diapsid. Parietal foramen with vestigeal pineal eye present. Quadrate is fixed.

(3) Vertebrae amphicoelous or biconcave. Numerous abdominal ribs present.

(4) Teeth acrodont. Cloacal aperture transverse.

(5) Heart incompletely 4-chambered.

(6) No copulatory organ is male.

Example : Represented by a single living species, the "Tuatara" or *Sphenodon punctatum* of New Zealand.

□ *Sphenodon* is referred to a "living fossil" because it has retained many primitive characteristics of fossil or stem reptiles.

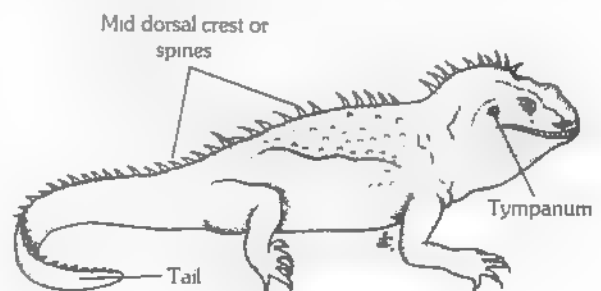


Fig : 1.7-69 Tuatara

Order 3. **Squamata** : (L. *squama* = scale or *squamatus* = scaly)

- (1) Advanced, small to medium, elongated.
- (2) Skull diapsid. Quadrate movable.
- (3) Vertebrae procoelous. Ribs single-headed.
- (4) Heart incompletely 4-chambered.
- (5) Cloacal aperture is transverse.
- (6) It includes snakes and lizards

Examples : *Phrynosoma*, *Draco*, *Hemidactylus*, *Heloderma*, *Chameleon*, *Ophisaurus*, *Anguis*, *Rhineura*, *Barkudia*, *Geko*, *Iguana*, *Varanus komodoensis*, *Python*, *Typhlops*, *Eryx johuii*, *Naja*, *Bungarus caeruleus*, *Dryophis*, *Vipera russelli*, *Hydrophis*, *Enhydryna*, *Crotalus*, *Ancistrodon*, *Micrurus*, *Lachesis*, etc.

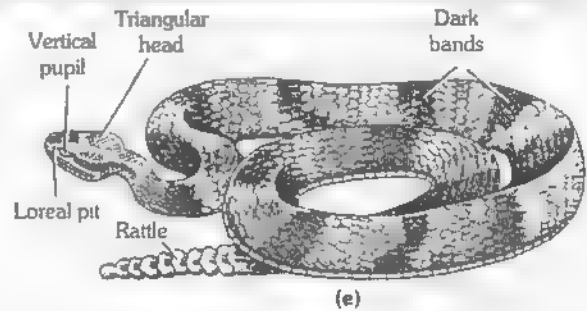
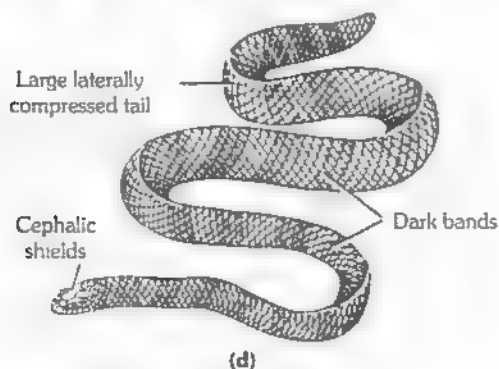
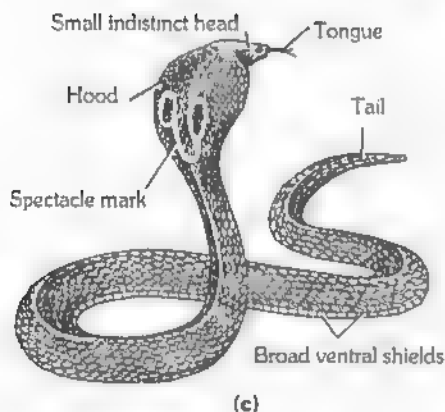
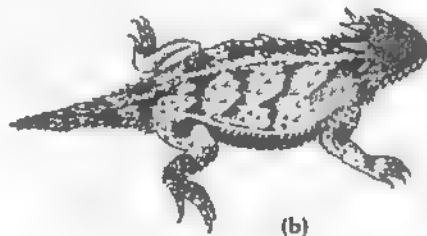
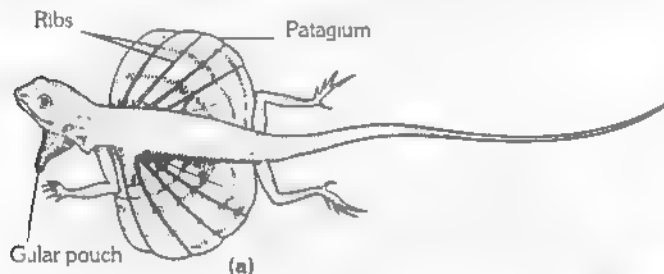


Fig : 1.7-70 (a) *Draco* (b) *Phrynosoma* (c) Indian cobra-*Naja naja* (d) Sea snake-*Hydrophis* (e) Rattle snake *Crotalus horridus*

Order 4. **Crocodylia** : (Gk. *krokodilos* = Crocodile)

- (1) Skin thick with scales bony plates and scutes.
- (2) Skull diapsid. Quadrate immovable. No parietal foramen. A pseudopalate present. Pineal gland absent.

(3) Ribs bicephalous. Abdominal ribs present.

(4) Heart completely 4-chambered.

(5) Cloacal aperture is a longitudinal slit.

Examples : *Crocodylus*, *Gavialis*, *Alligator*

□ The lung cavity of crocodile is separated from rest of body cavity by a muscular diaphragm, analogous to that of mammals.

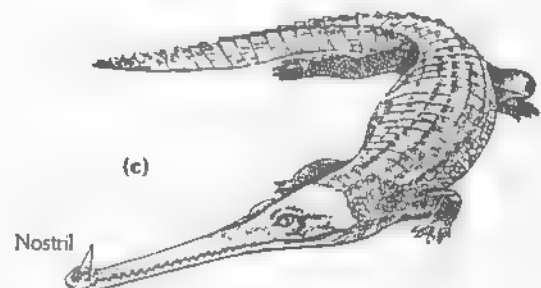
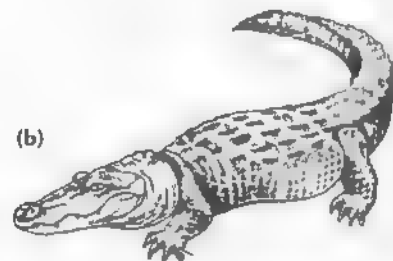
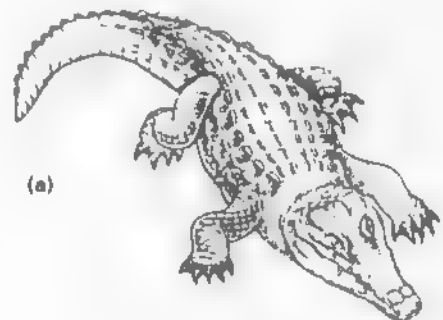


Fig : 1.7-71 (a) *Crocodylus palustris* (Indian freshwater crocodile) (b) *Alligator mississippiensis* (American alligator) (c) *Gavialis gangeticus* (Gavial or gharial)



Table : 1.7-13 Common Names

<i>Testudo</i>	–	Tortoise
<i>Dermochelys</i>	–	Leather back turtle
<i>Trionyx</i>	–	Soft shelled turtle
<i>Chelonia mydas</i>	–	Green turtle
<i>Kachuga</i>	–	Terrapin
<i>Sphenodon</i>	–	Tuatara
<i>Crocodylus</i>	–	Maggar
<i>Alligator</i>	–	Alligator
<i>Gavialis</i>	–	Gharial

**Lizards**

<i>Hemidactylus</i>	–	Wall/house lizard
<i>Uromastix</i>	–	Spiny tailed lizard
<i>Calotes</i>	–	Garden lizard
<i>Draco</i>	–	Flying dragon
<i>Phrynosoma</i>	–	"Horned toad"
<i>Mabouia</i>	–	Skink
<i>Varanus</i>	–	Monitor lizard
<i>Heloderma</i>	–	Gila monster
		Beaded lizard
<i>Ophisaurus</i>	–	Glass snake
<i>Anguis</i>	–	Slow worm
		Blindworm
<i>Rhineura</i>	–	Worm lizard
<i>Iguana</i>	–	Collared lizard

**Snakes (Nonpoisonous)**

<i>Typhlops</i>	–	Blind snake
<i>Ptyas (Zamenis)</i>	–	Rat snake
<i>Tropidonotus</i>	–	Grass snake
		Pond snake
<i>Lycodon</i>	–	Wolf snake
<i>Dendrophis</i>	–	Tree snake
<i>Dryophis</i>	–	Whip snake
<i>Eryx johnii</i>	–	Sand Boa

**Snakes (Poisonous)**

<i>Naja naja</i>	–	Cobra
<i>Naja hannah</i>	–	King cobra
<i>Bungarus</i>	–	Krait
<i>Viper russelli</i>	–	Pitless viper
<i>Ancistrodon</i>	–	Pit viper
<i>Crotalus</i>	–	Rattle snake
<i>Hydrophis</i>	–	Sea snake
<i>Enhydrina</i>	–	Sea snake
<i>Micrurus</i>	–	Coral snake

**Class Aves – The Birds**(L. *avis* = bird) or (Gk. *ornis* = bird)**General Characters**

(1) Feather-clad, air-breathing, warm-blooded, oviparous, bipedal flying vertebrates.

(2) Limbs are two pairs. Forelimbs are modified as wings for flying. Hind limbs or legs are large, and variously adapted for walking, running scratching, perching, food capturing, swimming or wading, etc.

(3) Exoskeleton is epidermal and horny.

(4) Skin is dry and devoid of glands except the oil or preen gland at the root of tail.

(5) Pectoral muscles of flight are well developed.

(6) Skull smooth and monocondylic, bearing a single occipital condyle. Cranium large and dome-like. Sutures indistinct.

(7) Vertebral column short. Centra of vertebrae heterocoelous (saddle-shaped).

(8) Sternum large, usually with a vertical, mid ventral keel for attachment of large flight muscles.

(9) Ribs double-headed (bicephalous) and bear posteriorly directed uncinate processes.

(10) Both clavicles and single inter clavicle fused to form a V-shaped bone, called furcula or wishbone or merry-thought bone.

(11) Heart completely 4-chambered. There are neither sinus venosus or truncus arteriosus. Only right aortic (systemic) arch persists in adult. Renal portal system vestigial. Blood corpuscles nucleated.

(12) Birds are the first vertebrates to have warm blood. Body temperature is regulated (homiothermous).

(13) Respiration by compact, spongy, nondistensible lungs continuous with thin air-sacs.

(14) Larynx without vocal cords. A sound box or syrinx, producing voice, lies at or near the junction of trachea and bronchi.

(15) Kidneys metanephric and 3-lobed. Ureters open into cloaca. Urinary bladder absent. Birds are ureotelic. Excretory substance of urates eliminated with faeces.

(16) Sexes separate. Sexual dimorphism is well marked in some birds like peacock and parrot.

(17) Fertilization internal, preceded by copulation and courtship. Females oviparous.

(18) Eggs develop by external incubation. Cleavage discoidal, meroblastic. Development direct, Extra-embryonic membranes (amnion, chorion, allantois and yolk-sac) present (Amniota).

(19) Parental care is well marked.

**Classification of Aves :** Birds show less diversification than any other group of vertebrate animals. 25 to 30 avian orders are recognized depending on the taxonomist. Class Aves is first divided into two subclasses.

(a) **Sub-Class I. Archaeornithes** : (Gk. *archaios* = ancient ; *ornithos* = bird)

(1) Extinct, archaic, Jurassic birds of Mesozoic Age, about 155 million years ago.

(2) Wings primitive, with little power of flight.

(3) Vertebrae amphicoelous.

(4) Sternum without a keel.

(5) Thoracic ribs slender, without uncinate processes. In *Archaeopteryx* beak in toothed.

This sub-classes includes a single order

Order **Archaeopterygiformes** : Example : *Archaeopteryx lithographica*, from Jurassic of Bavaria, Germany; one specimen lying in the British museum, London, the other lying in the Berlin.

(b) **Sub-class II. Neornithes** : (Gk. *neos* = modern ; *ornithos* = Birds)

(1) Modern as well as extinct post-Jurassic birds.

(2) Wings usually well-developed and adapted for flight, with few exceptions.

(3) Teeth absent except in some fossil birds.

(4) Vertebrae heterocoelous in living forms

(5) Sternum usually with a keel.

(6) Thoracic ribs usually with uncinate processes.

(7) Abdominal ribs absent

This sub-class is divisible into 4 super-orders:

**Super-order 1. Odontognathae** : (Gk. *odontos* = teeth)

(1) Extinct, Upper Cretaceous birds

(2) Jaws bear teeth, "so advantageous for catching fish".

Order 1. **Hesperornithiformes**

Example – *Hesperornis*, *Enaliornis*, *Baptornis*, etc.,

Order 2. **Ichthyornithiformes**

Examples – *Ichthyornis*, *Apatornis*.

**Super-order 2. Palaeognathae or Ratitae** : (Gk. *palaios* = old, *gnathos* = jaw) or (L. *ratit* = raft)

(1) Modern big-sized, flightless, running birds, without teeth.

(2) Wings vestigial or rudimentary; feathers devoid of interlocking mechanism.

(3) Rectrices absent or irregularly arranged.

(4) Oil gland is absent, except in *Tinamus* and *Kiwi*.

(5) Skull is dromaeognathous or palaeognathous that is, vomer is large and broad and interpolated between palatines.

(6) Sternal keel vestigial, absent or flat, raft-like.

(7) Uncinate processes are vestigial or absent.

(8) Clavicles are small or absent.

(9) Pectoral muscles poorly developed

(10) Syrinx is absent

The flightless birds or ratites are not represented in India. They are grouped in 7 orders as follows;

Order 1. **Struthioniformes** : (Gk. *struthio* = ostrich + form)

(1) Legs strongly developed, each with two toes (3rd and 4th) with stunted nails.

(2) Pubes form a ventral symphysis.

Examples : True ostriches (*Struthio camelus*) of Africa and western Asia (Arabia).

Order 2. **Rheiformes** : (Gk. *Rhea* = mother of Zeus + form)

Examples : American ostriches or common rhea (*Rhea americana*) represented by two species in South American pampas; Darwin's rhea (*Pteronemia pennata*).

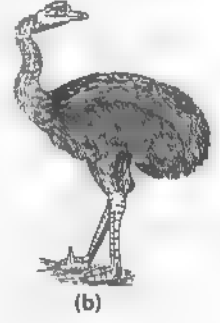
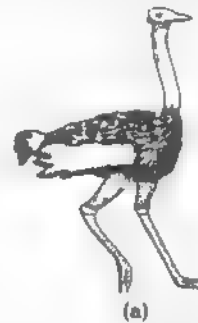


Fig : 1.7-72 (a) Ostrich (b) Rhea

Order 3. **Casuariformes**

Examples : Cassowaries (*Casuaris*) of Australia, and New Guinea and Emus (*Dromaius novaehollandiae*) of New Zealand.

Order 4. **Apterygiformes**

Examples : Kiwis (*Apteryx*) of New Zealand.

Order 5. **Dinornithiformes**

Examples : Moas (*Dinornis maximus*) of New Zealand

Order 6. **Aepyornithiformes**

Examples : Giant Elephant-birds (*Aepyornis titan*) *Mulleornis* of Africa and Madagascar.

Order 7. **Tinamiformes**

Examples : Tinamou (*Tinamus*), *Eudromia*

**Super-order 3. Impennae**

Order 1. **Sphenisciformes**

Examples : Penguins (*Aptenodytes*) Southern Hemisphere.

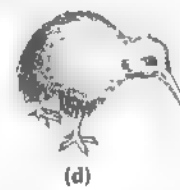
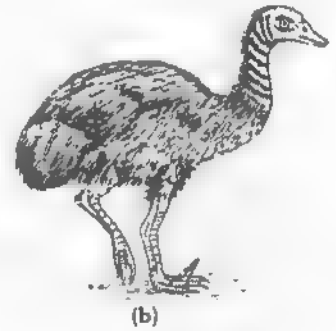
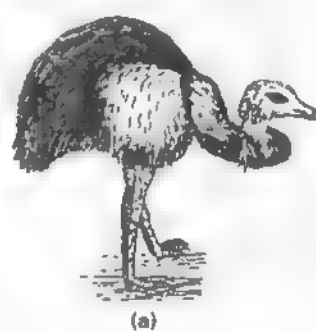


Fig : 1.7-73 (a) Cassowary (b) Emu (c) Tinamou (d) Kiwi (e) Penguin

**Super order 4. Neognathae**

- (1) Most modern, usually small-sized. Flying birds.
- (2) Wings well-developed; feathers with interlocking mechanism.
- (3) Rectrices present and arranged regularly.
- (4) Pterylae are regular.
- (5) Oil gland is present.
- (6) Skull is neognathous, that is, vomer is short allowing palatines to meet.
- (7) Sternum with a well-developed keel.
- (8) Uncinate processes are present.
- (9) Pygostyle is present

The super-order Neognathae includes several orders. For the sake of study they may be grouped into at least 6 homogenous ecological groups, as follows :

**Group A. Arboreal Birds** : Under this group may be placed the majority of birds spending most of their lives in and around shrubs and trees.

**Order 1. Passeriformes**

(*L. passer* = sparrow + form)

This is the largest of all the bird orders including half of the known species. Feet are adapted for perching, while beaks are adapted for cutting.

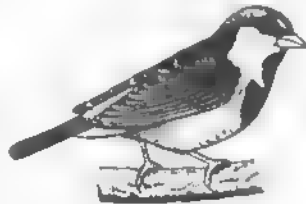


Fig : 1.7-74 House sparrow

Examples : *Passer domesticus*, *Corvus splendens*, common myna (*Acridotheres tristis*).

**Order 2. Piciformes** : (*L. picus* = wood pecker + form) It includes woodpeckers, toucans, sap-suckers and their allies.

Examples : Yellow fronted pied woodpecker (*Dendrocopos maharattensis*).

**Order 3. Columbiformes** : (*L. = columba* = dove + form) It includes doves and pigeons.

Examples : Blue rock pigeon (*Columba livia*), Green pigeon (*Crocopus*), extinct dodo (*Raphus*).

**Order 4. Psittaciformes** : (*L. = psitacus* = parrot + form)

It includes parrots, parakeets, cockatoos, macaws, love-birds, etc., denizens of the equatorial jungles.

Examples : Large Indian parakeet (*Psittacula eupatria*), green parrot (*psittacula krameri*).



Fig : 1.7-75 Parrot

**Group B. Terrestrial Birds** : These birds are perfectly able to fly but spend most of their time walking or running on ground.

**Order 5. Galliformes** : (*L. gallus* = a cock + form) It includes gamebirds notable for their palatability, massive scratching feet, short and powerful flight and largely graminivorous diet.

Examples : Red jungle fowl (*Gallus*), peafowl (*Pavo cristatus*).



Fig : 1.7-76 Peacock

**Order 6. Cuculiformes** : (*L. = cuculus* = cuckoo + form) It includes cuckoos and their allies.

Examples : Cuckoo (*Cuculus canorus*), Koel (*Eudynamis scolopaeus*), Crow-pheasant (*Centropus sinensis*).

**Group C. Swimming and Diving Birds**

**Order 7. Anseriformes** : (*L. anser* = goose + form) Aquatic birds such as geese, swans and ducks belong to this order.

Examples : Wild duck or mallard (*Anas*), common teal (*Nettion crecca*), bar-headed goose (*Anser indica*)

**Order 8. Coraciiformes** : (*Gk. korax* = crow or raven + form) It includes kingfishers and their allies.

Examples : White breasted kingfisher (*Halcyon smyrnensis*), pied kingfisher (*Ceryle rudis*), bee eater (*Hoopoe*).

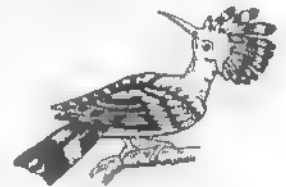


Fig : 1.7-77 Hoopoe

**Order 9. Gaviformes** : (*L. gavia* = sea mew + form) It includes marine birds, called loons (gavia) represented by only four species.

**Order 10. Podicipediformes or Colymbiformes** (*Gk. kolymbas* = diving bird).

It includes grebes (Podicipes), often called divers because of their habits.

**Order 11. Procellariiformes**

(*L. Procella* = a tempest + form).

It includes tube-nosed, long and oily winged seabirds such as albatrosses (Diomedea), Petrels (Procellaria), shearwaters.



Fig : 1.7-78 Albatross

**Order 12. Pelecaniformes** : (*L. pelicanus* = pelican + form) It includes pelicans, darters, gannets and cormorants.

Examples : Pelicans (*Pelecanus*), little cormorant (*Phalacrocorax niger*)

**Group D. Shore Birds and Wading Birds**

These aquatic birds seldom swim or dive beneath the water to any great extent.

**Order 13. Charadriiformes** : (*NL. charadrius* = genus of plovers + form) This order includes a rather diverse group of water frequenting shore birds characterized by long wading legs, webbed toes and mudprobing beaks.

Examples : Red wattled lapwing (*Lobivanelius indicus*)

**Order 14. Ciconiiformes** : (*L. ciconia* = a stork + form)

It includes long-legged, marshy wading birds with long snake-like neck and javelin or pincer-like beak for piercing their aquatic prey.

Examples : Cattle egret (*Bubulcus ibis*), heron (*Ardea herodias*), spoonbill (*Platalea leucorodia*), stork (*Ciconia*), flamingo (*Phonicopterus*).

**Order 15. Gruiformes** : (*L. grus* = crane + form) It includes crane-like wading birds with long legs and partially webbed feet.

Examples : Common coot (*Fulica atra*),

**Group E. Birds of Prey**

Order 16. **Falconiformes** : (L. falco = falcon + form)

The diurnal birds of prey with sharp hooked beaks and strong curved claws

**Table : 1.7-14 Flightless Birds**

Common Names	Genus	Distribution
1. African ostrich	<i>Struthio</i>	Africa and Arabia
2. South American	<i>Rhea</i>	South America
3. Cassowary	<i>Casuarus</i>	Australia and New Guinea
4. Emu	<i>Dromaius</i>	Australia
5. Tinamou	<i>Tinamus</i>	South America
6. Kiwi	<i>Apteryx</i>	New Zealand

**Table : 1.7-15 Types of Beaks in Birds**

Type	Example
1. Seed eating	Sparrow
2. Cutting	Crow
3. Fruit eating	Parrot
4. Insect eating	Hoopoe
5. Fish eating	Kingfisher
6. Flower probing	Humming bird
7. Spatulate	Spoonbill
8. Water and mud straining	Duck
9. Tearing and piercing	Eagle and owl

**Table : 1.7-16 Types of Feet in Birds**

Type	Example
1. Perching	Sparrow
2. Raptorial	Owl
3. Scratching	Fowl
4. Swimming	Duck
5. Running or cursorial	Ostrich
6. Climbing and clinging	Woodpecker
7. Wading	Jacana and Heron

**Table : 1.7-17 Common Names**

<i>Passer domesticus</i>	—	House sparrow
<i>Corvus splendens</i>	—	House crow
<i>Eudynamis scolopaceus</i>	—	Koel
<i>Upupa epops</i>	—	Hoopoe
<i>Pseudogyps bengalensis</i>	—	Bengal vulture
<i>Psittacula eupatria</i>	—	Indian parrot
<i>Psittacula krameri</i>	—	Rose ringed parakeet
<i>Phoenicopterus roseus</i>	—	Flamingo
<i>Pavo cristatus</i>	—	Peacock or Mor
<i>Milvus migrans</i>	—	Kite
<i>Bubo bubo</i>	—	Great horned owl
<i>Dinopium benghalensis</i>	—	Woodpecker
<i>Columba livia</i>	—	Common rock pigeon

**Class-Mammalia**

(L. *mamma* = breast)

**General characters**

(1) Hair-clad, mostly terrestrial, air-breathing, warm blooded, viviparous, tetrapod vertebrates.

(2) Limbs 2 pairs, pentadactyle, each with 5 or fewer digits. Hind limbs absent in cetaceans and sirenians.

(3) Exoskeleton includes lifeless, horny, epidermal hairs, spines, scales, claws, nails, hoofs, horns, bony dermal plates, etc.

(4) Skin richly glandular containing sweat, sebaceous (oil) and sometimes scent glands in both the sexes. Females also have mammary glands with teats producing milk for suckling the young.

(5) Endoskeleton thoroughly ossified. Skull dicondylic having 2 occipital condyles. Cranium large. A single zygomatic arch present. Pterygoids small, scale-like. Otic bones fused into petrotic which forms tympanic bulla with tympanic. Each half of lower jaw made of a single bone, the dentary, articulating with squamosal of skull. Vertebrae with terminal epiphyses and flat centra (acoelous). Cervical vertebrae usually 7. Ribs bicephalous. Coracoid vestigial.

(6) Teeth are of several types (heterodont), borne in sockets (thecodont) and represented by two sets (diphyodont).

(7) Respiration always by lungs (pulmonary). Glottis protected by a fleshy and cartilaginous epiglottis. Larynx contains vocal cords.

(8) Heart 4-chambered with double circulation.

(9) Kidneys metanephric.

(10) Brain highly evolved. Both cerebrum and cerebellum large and convoluted. Optic lobes small and 4 in number called corpora quadrigemina. Corpus callosum present connecting both cerebral hemispheres. Cranial nerves 12 pairs.

(11) Senses well developed. Eyes protected by lids, the upper of which is movable. External ear opening protected by a large fleshy and cartilaginous flap called pinna. Middle ear cavity with 3 ear ossicles—malleus, incus and stapes. Cochlea of internal ear spirally coiled.

(12) Sexes separate.

(13) Fertilization internal preceded by copulation.

(14) Except egg-laying monotremes, mammals are viviparous, giving birth to living young ones.

(15) Development uterine.

**Classification of Mammalia** : Mammals have been thoroughly described and adequately classified. The main characters forming the basis of their classification into orders include :

(1) Mode of caring of their young,

(2) Nature of dentition

(3) Foot posture,

(4) Nails, claws and hoofs,

(5) Complexity of nervous system and

(6) Systematics.

(a) **Subclass I prototheria** : (Gk. protos = first ; therios = beast)

(1) Primitive, reptile-like, oviparous or egg-laying mammals.

(2) Mammary gland without nipples.

- (3) External pinna absent.
- (4) Corpus callosum not found.
- (5) Adult without teeth, they bear horny beak.
- (6) Testes abdominal
- (7) Female without uterus and vagina.

It has only one order :

Order **Monotremata** : (Gk. monos = single ; trema = opening), Cloacal opening present Confined to Australian Tasmania and New Guinea region.

Examples : *Monotremes*. Platypus or duckbill (*Ornithorhynchus*) spiny anteater (*Tachyglossus* = *Echidna*).



Fig : 1.7-79 (a) *Echidna*, (b) *Ornithorhynchus*

(b) **Sub class II. Theria** : (Gk. ther, = animal)

Subclass Theria is divided into two infraclasses : Metatheria and Eutheria.

**Infraclass 1. Metatheria** : (Gk. meta = between or after)

(1) Metatherians are pouched mammals; young born in very immature state

- (2) Corpus collosum absent.
- (3) Ovoviviparous.
- (4) Epipubic bone present.
- (5) Vagina and uterus are double.

Order 2. **Marsupialia** : (Gk. marsypion = pouch).

(1) Born in a very immature state, and complete their development attached to teats or nipples in the abdominal pouch or marsupium. (2) Usually 3 premolars and 4 molars in each jaw on either side. (3) Vagina double

Examples : Opossum (*Didelphis*), Kangaroo (*Macropus*), koala (*Phascolarctos*)

□ Kangaroo is the native of Australia.

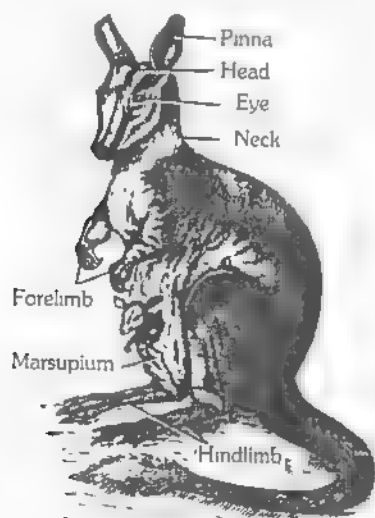


Fig : 1.7-80 Kangaroo

**Infraclass 2. Eutheria** : (Gk. eu = true ; therios ; beast)

- (1) Higher viviparous placental mammals without marsupium.
- (2) Corpus callosum present in brain.
- (3) Nipples are present in mammary gland.
- (4) Young born in a relatively advanced stage.
- (5) Cloaca absent but anus present.

(6) Dentition never exceeds  $\frac{3 \ 14.3}{3.14 \ 3} = 44$  . On the basis of

characteristics like skull, teeth and limbs, eutheria is arranged into 16 orders.

Order 1. **Insectivora** : (L. insectum = insect ; vorare = to eat)

- (1) Small mammals with long pointed snout.
- (2) Feet plantigrade, usually 5-toed, with claws.
- (3) Molars with pointed, peg-like cusps for insect feeding.

Examples : *Talpa*, *Sorex*, *Solenodon*, *Erinaceus*, *Paraechinus*

Order 2. **Dermoptera** : (Gk. derm = skin ; pteron = wing).

(1) Nocturnal in trees.

(2) A gliding mammal called flying lemur, resembling a flying squirrel. Membranous skin fold is present which help the animals in gliding from one tree to another.

Examples : One living genus *Cynocephalus* (= *Galaeoltheus*) with 2 species from South eastern Asia.

Order 3. **Chiroptera** : (Gk. Cheiros = hand ; pteron = wing)

(1) Flying mammals or bats in which forelimbs are modified into wings.

(2) Hind legs short and included in wing membrane.

(3) Second and third digits greatly longated supporting the skin fold forming the flight membrane.

(4) Eyes are small and vision weak.

(5) Ears have large pinnae.

(6) Radar system present.

(7) Nocturnal

(8) These may be food eating, insect eating or blood sucking in feeding habit.

Examples : *Pteropus*, *Rhinolophus*, *Desmodus*

Order 4. **Edentata** : (L. edentatus = toothless) Teeth absent or reduced to molars. Without enamel. These are nocturnal and herbivorous. Testes are abdominal.

Examples : *Myrmecophaga*, *Dasybus*, *Bradypus*.

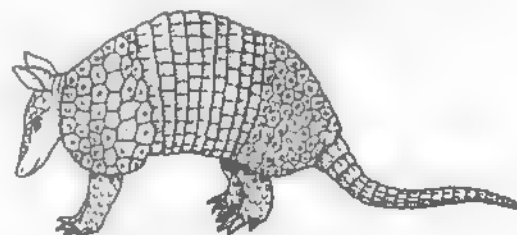


Fig : 1.7-81 Armadillo

Order 5. **Pholidota** : (Gk. pholis = a scale)

(1) Body covered with large overlapping scales with sparse hair in between. No teeth.

(2) Tongue long and protrusible, used to capture insects.

Examples Single genus of scaly anteaters pangolins (*Manis*)

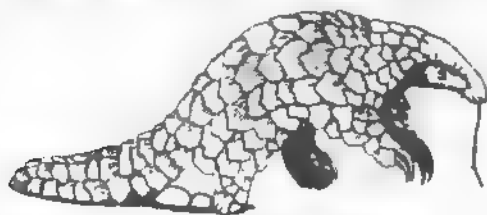


Fig : 1.7-82 Pangolin

Order 6. **Rodentia** : (L. rodo = gnaw).

- (1) Largest order including usually small gnawing mammals.
- (2) Each jaw with one pair of long, rootless, chisel-like incisors growing throughout life.
- (3) Canine absent.

Examples : *Rattus* (House rat), *Mus*, *Funambulus* (Squirrel)

Order 7. **Lagomorpha** : (Gk. logos = hare ; morpho = form)

With a second pair of small upper incisors behind first pair of large chisel like incisors. No canines.

Examples : *Oryctolagus* (Hare), *Lepus* (Rabbit), *Ochotona*.

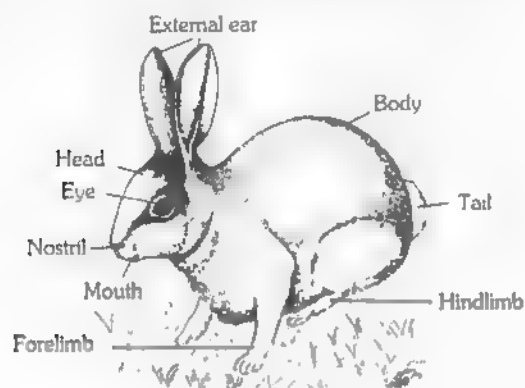


Fig : 1.7-83 Rabbit

Order 8. **Carnivora** : (L. caro = flesh ; vorare = to eat) Small to large predatory, flesh-eating mammals.

Examples : *Canis familiaris*, *C. lupus*, *C. aureus*, *Odobenus*, *Phoca*, *Panthera tigris*.

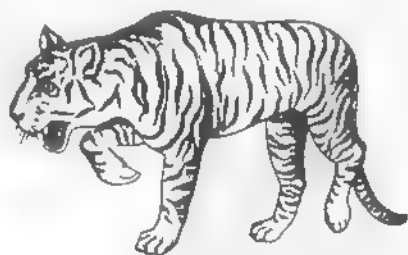


Fig : 1.7-84 Tiger

Order 9. **Cetacea** : (Gk. ketos or L. cetus = a whale)

- (1) Large marine fish-like mammals well adapted for aquatic life pectoral limbs modified into broad paddle-like flippers.
- (2) Tail divided in two broad horizontal fleshy flukes with a notch, used in propulsion.
- (3) No claws, no hind limbs and no external ears.
- (4) Mostly gregarious and carnivorous. The living Cetacea are divided into two suborders Odontoceti (toothed whales) and Mysticeti or Mysticoceti (whalebone whales).

Examples *Phocaena*, *Orcinus* (Killer whale), *Delphinus* (Dolphins), *Platanista Physeter*, *Balenoptera* (Blue whale).

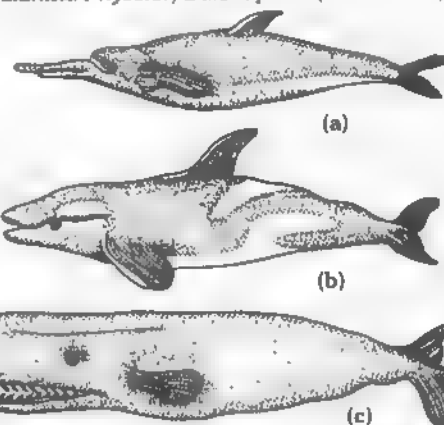


Fig : 1.7-85 (a) Dolphin, (b) Whale, (c) Sperm Whale

Order 10. **Sirenia** : (Gk. siren = sea nymph).

- (1) Large, clumsy herbivorous, aquatic mammals with paddle-like forelimbs, no hindlimbs and a flattened tail with horizontal lateral fleshy flukes with or without a notch.
- (2) No external ears.
- (3) Muzzle blunt. Hairs few.
- (4) Stomach complex.
- (5) Inhabit estuaries and coastal sea.

Examples : *Trichechus* (Manatees), *Dugong* (Halicore), recently extinct Steller's sea-cow (*Rhytina*).



Fig : 1.7-86 Manatee

Order 11. **Tubulidentata** : (L. tubulus Tube like ; dens = tooth) With tubular mouth tongue protrusible, no incisor or canines, limbs clawed and adapted for digging ant and termites nests.

Examples : Single genus of pig-like aardvark or Cape anteater (*Orycteropus*) of South Africa

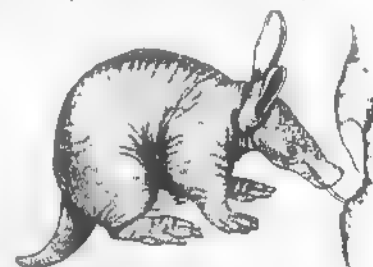


Fig : 1.7-87 Aardvark

Order 12. **Proboscidea** : (Gk. pro = In front ; boskein = to eat)

- (1) Largest living land animals having large heads, massive ears, thick practically hairless skins (pachyderm).
- (2) Bulky straight legs and 3 to 5 toes with small, nail like hoofs.

(3) Conspicuous feature is the nose and upper lip modified as an elongated flexible proboscis or trunk. 2 upper incisors elongated as ivory tusks.

(4) Cheek teeth lophodont.

Examples : *Elephas maximus* (Indian elephant), *Loxodonta africana* (African elephant), *Elephas cyclotis*.

Order 13. **Hyracoidea** : (Gk. hyrax = shrew ; eidos = form)

Small, guinea-pig like mammals distantly related to elephants. No canines. Cheek teeth lophodont.

Example : *Hyrax (Procavia)* from S. Africa, Syria and Arabia.

Order 14. **Perissodactyla** : (Gk. perissos = odd ; dactylos = toes)

The odd-toed hoofed mammals or ungulates have an odd number of toes (1 or 3) incisors present in both jaws.

Examples : *Equus caballus* (Horse), *Equus asinus* (Ass), *Equus zebra* (Zebra)

Order 15. **Artiodactyla** : (Gk. artios = even ; dactylos = digit)

(1) The even-toed hoofed mammals having an even number of toes (2 or 4)

(2) Incisors and canines in upper jaw usually lacking.

(3) Stomach 4 – chambered.

(4) Many with antlers or horns.

Examples : *Sus*, *Hippopotamus amphibius*, *Camelus*, *Cervus*, *Moschus*, *Ovis*.

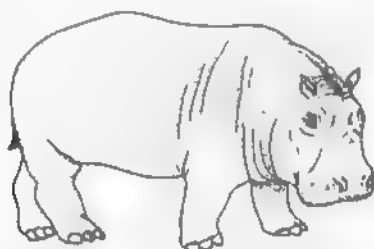


Fig : 1.7-88 Hippopotamus

Order 16. **Primates** : (L. primus = of the first rank)

(1) Generalized or primitive mammals except for the great development of brain.

(2) Mostly arboreal.

(3) First digit usually opposable, an adaptation for grasping.

(4) Eyes typically large and turned forward

Example – *Gibbon*, *Mandrillus*, *Chimpanzee*, *Ateles*, etc.

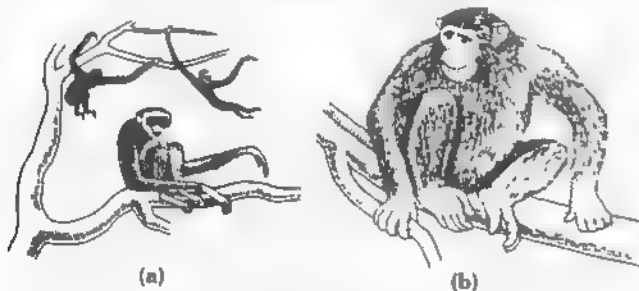


Fig : 1.7-89 (a) Gibbon, (b) Chimpanzee

Table : 1.7-18 Common Names

<i>Canis familiaris</i>	–	Dog
<i>Felis domestica</i>	–	Cat
<i>Panthera leo</i>	–	Lion
<i>Panthera tigris</i>	–	Tiger
<i>Acinonyx jubatus</i>	–	Cheetah
<i>Lutra</i>	–	Otter
<i>Herpestes</i>	–	Mongoose
<i>Trichechus</i>	–	Manatee
<i>Halicorn</i>	–	Dugong
<i>Equus caballus</i>	–	Horse
<i>Equus asinus</i>	–	Ass
<i>Rhinoceros unicornis</i>	–	Indian rhinoceros
<i>Diceros bicornis</i>	–	African rhinoceros
<i>Tapirus Indicus</i>	–	Malayan Tapir
<i>Hippopotamus amphibius</i>	–	Hippopotamus
<i>Camelus dromedarius</i>	–	Arabian camel
<i>Cervus</i>	–	Red deer
<i>Giraffa camelopardalis</i>	–	Giraffe
<i>Sus scrofa</i>	–	Wild boar
<i>Bubalus bubalis</i>	–	Water buffalo
<i>Ateles paniscus</i>	–	Spider monkey
<i>Macaca mulatta</i>	–	Rhesus monkey
<i>Macaca silenus</i>	–	Lion-tailed macaque
<i>Hylobates lar</i>	–	Gibbon
<i>Papio</i>	–	Baboon
<i>Presbytis</i>	–	Langur
<i>Pongo</i>	–	Orang-utan
<i>Pan</i>	–	Chimpanzee

## Tips & Tricks

▣ Pelagic animals : Animals living in open water and include both zooplanktons and nektons.

▣ Nektons are those animals which actively swim in open water while neustons are those animals which float or swim in surface water. Neritic are the animals found in coastal water.

▣ Archaeocyte cells of sponges are totipotent cells.

▣ Dermal ostia of sponges are analogous to mouth, while osculum is analogous to anus.

▣ Olynthus stage : It is a stage present during the development of all syconoid sponges. It is a hypothetical ancestors of sponges.

▣ Hilsa is the only Indian fish that migrates from the seas to the river for breeding.

- ✎ Stone fish is the most poisonous fish.
- ✎ Bombay duck is a bony fish.
- ✎ Seabass (*Diploprion*) is hermaphrodite fish.
- ✎ Ampullae of Lorenzini are peculiar sense organs on their snout to note the thermal change in water.
- ✎ Lateral line is with neuromast organs which have rheoreceptors and note changes in water currents.
- ✎ Electric organs of *Torpedo* are modified muscles. These produce an electric current of 50-60 volts
- ✎ All the cartilaginous fishes are marine, while bony fishes are either marine or fresh-water.
- ✎ Pectoral fins of fishes act as balancers, pelvic fins as brakes and caudal fin as steering organ in locomotion.
- ✎ *Echeneis* (Sucker fish or *Remora*) : Dorsal fin is modified into sucker. It shows commensalism with sharks, whale, etc. as is attached on their ventral side by its sucker for dispersal.
- ✎ *Latimeria* (*Coelacanth*) : A lobe-finned bony fish and is about 70 million years old. First reported by Miss Latimer. Called living fossil.
- ✎ The Arrow poison frogs secrete a powerful poison from their skin which can cause instant death.
- ✎ Golden dart poison frog from South America is the most poisonous frog. One adult frog contains enough poison to kill 2200 people.
- ✎ Largest amphibians. Japanese Giant Salamander which grows to a length of 1.6 m. Smallest amphibian. One of the South American arrow poison frogs, which measures upto 1.3 cm.
- ✎ *Amphiuma* (Congo-eel) – Has largest sized RBCs (75  $\mu\text{m}$ ). It has gill slits but no gills, called derotremetons condition.
- ✎ *Rhacophorus* (Flying frog) – Glides on the support of webs. Also has adhesive discs on digits.
- ✎ *Hyla* (Tree frog) – Climbs up the tree with adhesive discs on the tips of digits. Skin is with hygroscopic glands.
- ✎ *Salamandra* (Spotted Salamander) – Viviparous amphibian.
- ✎ The king cobra of India is the only snake in the world that builds a nest.

- ✎ Most poisonous snake-king cobra.
- ✎ Fangs of poisonous snake are maxillary teeth.
- ✎ Largest snake-python/*Anaconda*, may grow upto 10 meter in length.
- ✎ Smallest snakes. Thread snake, less than 2 cm. in length.
- ✎ *Seymouria* It was one such ancestral reptile which probably started laying eggs on land in the permian period. It was a lizard like sluggish creature. It was a “connecting link” between amphibian and reptiles.
- ✎ *Anguis* (European glass snake-limbleless-lizard), *chameleon pumilus*, *russelli* (the Russell’s viper), *Hydrophis* (sea snake)-All are viviparous.
- ✎ T.H. Huxley said “birds are glorified reptiles”. The feathers are highly modified reptilian scales. Birds have scales on their legs. Their eggs resemble reptilian eggs in general but have a calcareous shell.
- ✎ Humming bird is the only bird which can fly backward as well as forward
- ✎ Kiwi lays the largest egg in proportion to its own size
- ✎ Vision and hearing are the most highly developed senses in a bird
- ✎ Famous Indian Ornithologist – Dr. Salim ali. He was known as “Bird man of India”.
- ✎ Keoladeo Ghana National Park, Bharatpur, Rajasthan and Chilka lake Bird sanctuary Balagaon, Orissa are famous of birds.
- ✎ The Indian one horned Rhinoceros is the second largest land animal in India.
- ✎ Walrus – Marine carnivore. Its tusks are upper canines and are used for digging to locate molluscs.
- ✎ Koala Bear lives without water on Eucalyptus leaves. The water in the leaves meets its requirement of water.
- ✎ Kangaroo rat never drinks water in its entire life.
- ✎ Giant panda is one of the rarest animals in the world. Pandas rarely breed in captivity. Giant pandas live only in high mountains of China.





## Ordinary Thinking

### Objective Questions

#### Important terms and classification of animals

1. Larva is found in [Odisha JEE 2008]  
(a) Vertebrates (b) Invertebrates  
(c) Both (a) and (b) (d) None of these
2. Poikilotherms are also known as [Odisha JEE 2008]  
(a) Isotherm (b) Ectotherm  
(c) Endotherm (d) Heterotherm
3. Animals/organisms floating on the surface of water are [CBSE PMT 1998; BHU 1998, 2001]  
(a) Plankton (b) Pelagic  
(c) Benthon (d) Neritic
4. The body of the animal can be divided into identical halves in only one plane is [J & K CET 2010]  
(a) Asymmetry (b) Bilateral symmetry  
(c) Radial symmetry (d) Biradial symmetry
5. Radial symmetry occurs in [HPMT 1995; Chd. CET 2003; MP PMT 2006]  
(a) Fishes (b) Molluscs  
(c) Star Fishes (d) Sponges
6. The space between body wall and alimentary canal lined by mesoderm is called [J & K CET 2010]  
(a) Acoelom (b) Pseudocoelom  
(c) Coelom (d) None of these
7. In coelomates, the problem of diffusion of food from gut to tissues is solved by [EAMCET 2009]  
(a) The presence of coelomic fluid  
(b) Churning the food within the body cavity  
(c) Developing a circulatory system  
(d) Developing gut associated glands
8. Trochophore larva occurs in [BHU 1995; Odisha JEE 2005]  
(a) Annelida and Porifera  
(b) Coelenterata and Annelida  
(c) Mollusca and Coelenterata  
(d) Annelida and Mollusca
9. An animal which comes out at night and hides during day time is [CPMT 1998]  
(a) Diurnal (b) Nocturnal  
(c) Cursorial (d) Arboreal
10. Parasites capable of living without a host are called [Odisha JEE 2005]  
(a) Facultative (b) Permanent  
(c) Obligate (d) None of these
11. Enterocoelous coelom is found in [Odisha JEE 2005]  
(a) Deuterostomia (b) Astomia  
(c) Protostomia (d) Blastostomia
12. Non-chordates have [BCECE 2005]  
(a) Notocord  
(b) Dorsal tubular nerve chord  
(c) Pharyngeal gills cleft  
(d) Absence of hepatic portal system
13. Cell aggregate plan is found in [AFMC 1997]  
(a) Cnidarians (b) Sponges  
(c) Roundworms (d) Flatworms
14. Which of the following statements is false [Kerala CET 2005]  
(a) Male roundworm is smaller than female  
(b) Earthworms are hermaphrodite  
(c) Echinoderms are protostomous coelomates  
(d) Human teeth are anatomically comparable to scales of shark  
(e) Hair is derivative of skin
15. Which of the following phylum are included in enterozoa [RPMT 2001]  
(a) Annelida, Mollusca, Porifera  
(b) Echinodermata, Hemichordata, Porifera  
(c) Mollusca, Arthropoda, Hemichordata  
(d) Porifera, Mollusca, Arthropoda
16. Tube-within-a-Tube body plan is shown by  
(a) Coelenterates  
(b) Platyhelminthes  
(c) Aschelminthes (Nemethelminthes)  
(d) Porifers
17. Cold-blooded animals fall under the category of [DUMET 2010]  
(a) Ectotherms (b) Psychrotherms  
(c) Endotherms (d) Thermophiles
18. Blind sac body plan is shown by  
(a) Roundworms (b) Annelids  
(c) Coelenterates (d) Arthropods
19. What is characteristic of deuterostomes [DPMT 2001]  
(a) Spiral cleavage, blastopore becoming mouth  
(b) Radial cleavage, blastopore becoming anus  
(c) Spiral cleavage, blastopore becoming anus  
(d) Radial cleavage, blastopore becoming mouth
20. Mouth develops first in the embryo and anus is formed later in [BHU 2012]  
(a) Deuterostomes (b) Protostomes  
(c) Echinoderms (d) Chordates
21. Which of these statements are incorrect  
(i) Parapodia are lateral appendages in arthropods used for swimming  
(ii) Radula in molluscs are structures involved in excretion  
(iii) Aschelminthes are dioecious  
(iv) Echinoderm adults show radial symmetry  
(v) Ctenophorans are diploblastic [Kerala PMT 2011]  
(a) (i) and (ii) (b) (i) and (iii)  
(c) (i), (iv) and (v) (d) (iii) and (v)  
(e) (ii), (iii) and (iv)
22. In which triploblastic animal coelom is absent [WB JEE 2008, 11]  
(a) Platyhelminthes (b) Aschelminthes  
(c) Annelida (d) Arthropoda
23. On the basis of organisation, animals are grouped into [MP PMT 1997]  
(a) Metazoa and Eumetazoa (b) Protozoa and Metazoa  
(c) Protozoa and Parazoa (d) Parazoa and Metazoa

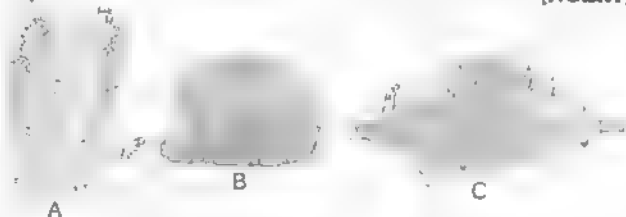
24. Radial symmetry occurs in  
[Chd. CET 1997; AFMC 2000; Kerala CET 2007]  
(a) Porifera and Coelenterata  
(b) Coelenterata and Echinodermata  
(c) Coelenterata and Platyhelminthes  
(d) Arthropoda and Mollusca
25. Coelom produced by splitting of mesoderm is [CPMT 1997]  
(a) Hydrocoel (b) Enterocoel  
(c) Schizocoel (d) None of the above
26. Which one of the following does not have larvae in its life cycle [Pb. PMT 1997]  
(a) Prawn (b) Earthworm  
(c) Crab (d) Cockroach
27. Coelom is cavity between alimentary canal and body wall enclosed by [CBSE PMT 1996; JIPMER 1997; JKCME 2002; J & K CET 2005]  
(a) Ectoderm and endoderm (b) Mesoderm and ectoderm  
(c) Ectoderm on both sides (d) Mesoderm on both sides
28. Tiny free living animals on the surface of water constitute [KCET 1999]  
(a) Zooplankton (b) Phytoplankton  
(c) Benthon (d) Symbionts
29. From the following statements select the wrong one [CBSE PMT 2005]  
(a) Millipedes have two pairs of appendages in each segment of the body  
(b) Prawn has two pairs of antennae  
(c) Animals belonging to phylum porifera are exclusively marine  
(d) Nematocysts are characteristic of the phylum cnidaria
30. An enterocoelomate invertebrate group is [APMEE 1999]  
(a) Annelida (b) Echinodermata  
(c) Arthropoda (d) Mollusca
31. Schizocoelomates and enterocoelomates are [AFMC 2006]  
(a) Acoelomates (b) True coelomates  
(c) Invertebrates (d) Echinoderms only
32. Metameric segmentation is the characteristic of [NCERT; HPMT 1993; CBSE PMT 2006]  
(a) Annelida and Arthropoda  
(b) Mollusca and chordata  
(c) Platyhelminthes and Arthropoda  
(d) Echinodermata and Annelida
33. A radially symmetrical diploblastic animal is [AFMC 1993]  
(a) Roundworm (b) Earthworm  
(c) *Hydra* (d) Liver Fluke
34. Radial symmetry is often exhibited by animals having [CBSE PMT 1994, 96, 97]  
(a) One opening of alimentary canal  
(b) Aquatic mode of living  
(c) Benthos/sedentary nature  
(d) Ciliary mode of feeding
35. Arboreal mammals have [Pb. PMT 1999]  
(a) Jumping character (b) Burrowing character  
(c) Climbing character (d) Flying character
36. In contrast to annelids the Platyhelminthes show [NCERT; CBSE PMT 2005]  
(a) Radial symmetry (b) Presence of pseudocoel  
(c) Bilateral symmetry (d) Absence of body cavity
37. Animal with pseudocoelom is [RPMT 2000; DPMT 2001; Kerala PMT 2006]  
(a) *Amia*/Leech (b) *Lepisma*/Liver Fluke  
(c) Dragon Fly/Jelly Fish (d) *Wuchereria*/Hookworm
38. Pseudocoelom develops from [CBSE PMT 1994; CPMT 2002; RPMT 2005]  
(a) Blastopore lip (b) Archenteron  
(c) Embryonic mesoderm (d) Blastocoel
39. A true coelom is absent in phylum  
Or  
Which of the following is pseudocoelomate [Odisha JEE 2009]  
(a) Nematoda (b) Annelida  
(c) Echinodermata (d) Mollusca
40. True coelom or body cavity occurs in [NCERT]  
(a) *Hydra* (b) *Taenia*  
(c) *Pheretima* (d) *Sycon*
41. Veliger larva occurs in phylum [DPMT 2001]  
(a) Mollusca (b) Echinodermata  
(c) Arthropoda (d) Cnidaria
42. Cell-tissue organisation occurs in [CBSE PMT 2000]  
(a) Liver fluke (b) Sponge  
(c) *Hydra* (d) Starfish
43. A list of animals is given below. Identify the animals with open circulatory system and choose the correct answer.  
(A) *Ascidia* (B) Cockroach  
(C) Earthworm (D) Prawn  
(E) Silverfish (F) Snail  
(G) Squid  
[Kerala CET 2002, 05; AMU (Med.) 2005]  
(a) B, D, F (b) A, B, D, F  
(c) C, D, E, G (d) B, D, E, F  
(e) A, B, D, F, G
44. Besides Annelida and Arthropoda metamerism is found in [NCERT; CBSE PMT 1995]  
(a) Cestoda (b) *Acanthocephala*  
(c) Chordata (d) Mollusca
45. Organisms attached to substratum generally possess [CBSE PMT 1995; AIIMS 1999]  
(a) Asymmetrical body  
(b) Radial symmetry  
(c) One single opening of digestive canal  
(d) Cilia on the surface to create water current

### Phylum-Porifera

1. Which one of the following categories of animals, is correctly described with no single exception in it [NCERT; CBSE PMT (Malina) 2012]  
(a) All reptiles possess scales, have a three chambered heart and are cold blooded (poikilothermal)  
(b) All bony fishes have four pairs of gills and an operculum on each side  
(c) All sponges are marine and have collared cells  
(d) All mammals are viviparous and possess diaphragm for breathing

2. Tissues are absent in the body of [CPMT 2009]  
(a) Sponge (b) Annelida  
(c) Platyhelminthes (d) Arthropoda
3. Which is not correct for sponges [Odisha JEE 2009]  
(a) Internal fertilization  
(b) External fertilization  
(c) Gemmule formation  
(d) Gametes are formed from epidermal cells
4. Ostia is present in [Odisha JEE 2011]  
(a) Poriferans (b) Coelenterates  
(c) Annelids (d) Molluscs
5. In porifera, skeleton forming cells are [MP PMT 2000; Odisha JEE 2012]  
(a) Sclerocytes (b) Archaeocytes  
(c) Thesocytes (d) Amoebocytes
6. Glass Rope sponge is [BVP 2000]  
(a) *Hyalonema* (b) *Euplectella*  
(c) *Scypha* (d) *Spongilla*
7. Sponges structure corresponding to mouth of other animals is [BHU 1999]  
(a) Incurrent canal (b) Ostium  
(c) Osculum (d) Excurrent canal
8. The most distinctive character of sponge is [EAMCET 1998]  
(a) Presence of choanocytes (b) Unicellular  
(c) Marine (d) Asexual reproduction
9. Canal system is a characteristic of [CPMT 1996; CBSE PMT 1999; RPMT 1999; BHU 2000, 02; Odisha JEE 2011]  
(a) *Hydra* (b) Sponge  
(c) Sea anemone (d) Sea urchin
10. Common bath sponge is [CBSE PMT 1995; MP PMT 2002]  
(a) *Spongilla* (b) *Euspongia*  
(c) *Leucosolenia* (d) *Sycon*
11. Body having meshwork of cell, internal cavities lined with food filtering flagellated cells and indirect development are the characteristics of phylum  
(a) Porifera (b) Mollusca  
(c) Protozoa (d) Coelenterate
12. In *Leucosolenia*, digestion takes place in the  
(a) Paragastric cavity (b) Stomach  
(c) Osculum (d) Food vacuole
13. *Parenchymula* (sponges free swimming larva) is the larva of [EAMCET 1998; CPMT 2000]  
(a) *Hydra* (b) *Ascaris*  
(c) *Pheretima* (d) *Leucosolenia*
14. Sponges are [BVP 2003]  
(a) Sessile (b) Planktonic  
(c) Free-swimming (d) Pelagic
15. Which sponge is given as a gift in Japan [CPMT 1998]  
(a) *Hyalonema* (b) *Euplectella*  
(c) *Tethya* (d) *Leucosolenia*
16. Water currents in *Leucosolenia* are produced by [AIIMS 1999; BHU 1999; DPMT 1999; HPMT 2002]  
(a) Choanocytes (b) Pinacocytes  
(c) Archaeocytes (d) Thesocytes

17. Members of phylum porifera are [CBSE PMT 2000; AFMC 2000; MH CET 2003]  
(a) Exclusively marine animals  
(b) Exclusively fresh water animal  
(c) Mostly fresh water animals but few are marine animals  
(d) Mostly marine animals but few are fresh water animals
18. Which sponge is found in the river [NCERT; RPMT 1999]  
(a) *Cliona* (b) *Spongilla*  
(c) *Sycon* (d) *Hyalonema*
19. What is found in a sponge [RPMT 1995; CPMT 1996, 2002, 10]  
(a) Choanocytes (b) Nematocytes  
(c) Amoebocytes (d) Both (a) and (c)
20. Which of the following is boring sponge [CPMT 1999]  
Or  
A sponge harmful to oyster industry is [AFMC 1997]  
(a) *Cliona* (b) *Chalina*  
(c) *Euplectella* (d) *Hyalonema*
21. Identify the names of the following figure from the given option [NCERT]



	A	B	C
(a)	<i>Euspongia</i>	<i>Sycon</i>	<i>Spongilla</i>
(b)	<i>Spongilla</i>	<i>Sycon</i>	<i>Eusporangia</i>
(c)	<i>Euspongia</i>	<i>Spongilla</i>	<i>Sycon</i>
(d)	<i>Sycon</i>	<i>Euspongia</i>	<i>Spongilla</i>

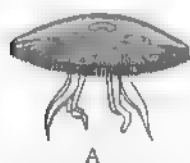
22. Classification of Phylum Porifera is based on [CBSE PMT 1991; WB JEE 2012]  
(a) Nutrition (b) Spicules  
(c) Locomotion (d) Reproduction
23. *Amphiblastula* is the larva of [AFMC 2001; CPMT 2002; RPMT 2005]  
(a) *Hydra* (b) *Sycon*  
(c) *Planaria* (d) *Leucosolenia*
24. What is left, when bathsponges dries up [AIIMS 2002]  
(a) Spicules (b) Holdfast  
(c) Tentacles (d) Spongin fibres
25. What will happen if a sponge is cut into maximum possible pieces [RPMT 2001]  
(a) These will die  
(b) These will differentiate  
(c) Every piece will form a sponge  
(d) Some pieces will develop in organs
26. Which of the following cell type is capable giving rise to other cell type in sponges [CPMT 1993; MH CET 2002; Pb. PMT 2004]  
Or  
Reproductive cells of sponges are formed from [CBSE PMT 1991]  
(a) Archaeocytes (b) Collenocytes  
(c) Thesocytes (d) Pinacocytes

27. Spongin fibres are secreted by [BVP 2000]  
 (a) Choanocytes (b) Pinacocytes  
 (c) Amoebocytes (d) Spongioblasts
28. The middle layer in body wall of porifera is [AIIMS 1999]  
 Or  
 The non-cellular layer present between pinacoderm and choanoderm in body wall of poriferans is known as [Odisha JEE 2012]  
 (a) Mesoderm (b) Mesenchyme  
 (c) Mesogloea (d) Mesentery
29. Sponges capture food particles with the help up [BVP 2001; MHCET 2002; RPMT 2005]  
 Or  
 Feeding in sponges takes place through [BHU 1999; CPMT 1999, 2005]  
 (a) Choanocytes (b) Pinacocytes  
 (c) Thesocytes (d) Trophocytes
30. Which of the following features is universally present in all sponges [MP PMT 2013]  
 (a) Marine habitat (b) Presence of spicules  
 (c) Presence of spongin fibres (d) Presence of spongocoel
31. Spicules of silica occur in [APMEE 2001]  
 (a) *Hyalonema* (b) *Sycon*  
 (c) *Leucosolenia* (d) *Grantia*
32. In most simple type of canal system of porifera, water flows through which one of the following ways [NCERT; WB JEE 2012]  
 (a) Ostia → Spongocoel → Osculum → Exterior  
 (b) Spongocoel → Ostia → Osculum → Exterior  
 (c) Osculum → Spongocoel → Ostia → Exterior  
 (d) Osculum → Ostia → Spongocoel → Exterior
33. One of the following is not a characteristic feature of sponges [NCERT; Kerala PMT 2010]  
 (a) Cellular level of organization  
 (b) Presence of ostia  
 (c) Intracellular digestion  
 (d) Body supported by chitin  
 (e) Indirect development
34. Internal asexual propagule of some fresh water sponges is [Kerala PMT 2006]  
 Or  
 Internal bud for overcoming unfavourable conditions in *Leucosolenia* is [CPMT 1996]  
 (a) *Gemmule* (b) *Planula*  
 (c) *Stereoblastula* (d) *Amphiblastula*
35. Skeleton made of spongin fibres occurs in [CPMT 2001; RPMT 2001]  
 (a) *Calcarea* (b) *Demospongiae*  
 (c) *Hexactinellida* (d) Both (a) and (b)
36. Digestion of food occurs in sponges *Leucosolenia* in  
 (a) Spongocoel  
 (b) Choanocytes followed by amoebocytes  
 (c) Amoebocytes  
 (d) Choanocytes
37. Venus Flower Basket belongs to Phylum  
 (a) Porifera (b) Coelenterata  
 (c) Echinodermata (d) Mollusca
38. Spicules are found in [J & K CET 2010]  
 (a) *Hydra* (b) *Planaria*  
 (c) *Sycon* (d) *Obelia*
39. Sponges are porifers because their bodies have [CPMT 1994; RPMT 2002]  
 (a) Spicules in skeleton (b) Several pores  
 (c) Canal system (d) All the above
40. Nerve cells do not occur in [NCERT; AMU (Med.) 2012]  
 (a) Nematodes (b) Mosquitoes  
 (c) Sponges (d) Coelenterates
41. Bath sponges is generally found in [CPMT 1992]  
 (a) Red Sea (b) Gulf Mexico  
 (c) Pacific Islands (d) Mediterranean sea
42. The simplest type of canal system in Porifera [CBSE PMT 1992]  
 Or  
 Type of spongocoel found in *Leucosolenia* is [CPMT 2001]  
 (a) Ascon type (b) Leucon type  
 (c) Sycon type (d) Radial type
43. Thesocytes serve as [CPMT 1992]  
 (a) Sex cells (b) Slime secreting cells  
 (c) Food reserve (d) Embryonic cells
44. Animals devoid of respiratory, excretory and circulatory organs are [HPMT 1993; DPMT 2002, 04]  
 (a) Tapeworms (b) Sponges (Porifera)  
 (c) Thread worms (d) Liver Fluke
45. Collar cells occur in [CPMT 1992, 93]  
 (a) Sponges (b) *Hydra*  
 (c) Sandworm (d) Star fish
46. Nutrition in sponges is  
 (a) Extracellular  
 (b) Intracellular  
 (c) First extracellular and then intracellular  
 (d) First intracellular and then extracellular
47. Carnine particle put above osculum of a sponge would be [CPMT 1993]  
 (a) Left there  
 (b) Ingested and digested  
 (c) Thrown away  
 (d) Ingested and thrown away by ostia
48. Canal system in porifera is not concerned with [AFMC 2005]  
 (a) Respiration (b) Nutrition  
 (c) Sexual reproduction (d) None of these
49. Which of the following are 'multicellular grade' organisms [AFMC 1997; BVP 2004]  
 (a) Sponges (b) Coelenterates  
 (c) Prokaryotes (d) Vertebrates
50. Sponges have evolved from [RPMT 1996]  
 (a) Ciliates (b) Flagellates  
 (c) Protozoans (d) Choanoflagellates
51. Which is universal for sponges [CBSE PMT 1996]  
 (a) Marine (b) Calcareous spicules  
 (c) Radial symmetry (d) High regenerative power
52. In sponges, canal system develops due to [CBSE PMT 1996]  
 (a) Gastrovascular system (b) Folding of inner walls  
 (c) Porous walls (d) Reproduction
53. Osculum occurs in [BHU 1997]  
 (a) Star Fish (b) Ray Fish  
 (c) *Hydra* (d) Sponge

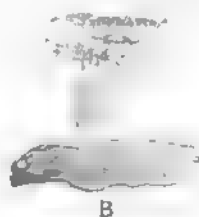
54. Incurrent canals are lined by [CPMT 1998]  
(a) Choanocytes (b) Pinacocytes  
(c) Porocytes (d) None of the above
55. Choanocytes in Ascon-type of canal system form lining of [NCERT; CPMT 1998]  
(a) Spongocoel (b) Porocyte  
(c) Apopyle (d) Incurrent canal
56. In case of poriferans, the spongocoel is lined with flagellated cells called [NEET 2017]  
(a) Ostia (b) Oscula  
(c) Choanocytes (d) Mesenchymal cells

### Phylum-Coelenterata

1. Larva of jelly fish (*Aurelia*) [Odisha JEE 2008]  
(a) Planula (b) Polyp  
(c) Medusa (d) Blastula
2. Highest degree of polymorphism is found in [J & K CET 2008]  
(a) Protozoa (b) Cnidaria  
(c) Platyhelminthes (d) Arthropoda
3. The dioecious animal is [J & K CET 2008]  
(a) Liverfluke (b) *Aurelia*  
(c) Tapeworm (d) Earthworm
4. Metagenesis refers to [AIPMT 2015]  
(a) Alternation of generation between asexual and sexual phases of an organisms  
(b) Occurrence of a drastic change in form during post embryonic development  
(c) Presence of a segmented body and parthenogenetic mode of reproduction  
(d) Presence of different morphic forms
5. Which of the following do not have polyp form [RPMT 1995]  
(a) Hydrozoa (b) Scyphozoa  
(c) Anthozoa (d) All the above
6. Which shows polymorphism [CPMT 1998; MP PMT 2009; BHU 2012]  
(a) *Physalia* (b) *Trypanosoma*  
(c) Termite (d) All of the above
7. Select the right option in which all the following figures are correctly identified [NCERT]



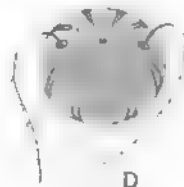
A



B



C



D

	A	B	C	D
(a)	<i>Adamsia</i>	<i>Aurelia</i>	<i>Pleurobrachia</i>	<i>Cnidoblast</i>
(b)	<i>Cnidoblast</i>	<i>Pleurobrachia</i>	<i>Adamsia</i>	<i>Aurelia</i>
(c)	<i>Aurelia</i>	<i>Adamsia</i>	<i>Cnidoblast</i>	<i>Pleurobrachia</i>
(d)	<i>Pleurobrachia</i>	<i>Cnidoblast</i>	<i>Aurelia</i>	<i>Adamsia</i>

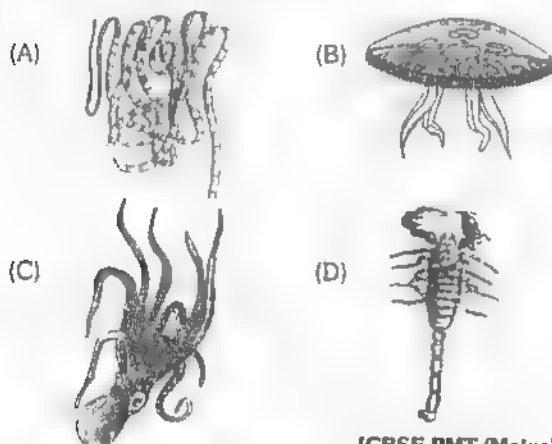
8. Most appropriate term to designate the life cycle of *Obelia* is [NCERT; BHU 2002]  
(a) Neoteny (b) Metagenesis  
(c) Metamorphosis (d) None of these
9. Which of the following does not belong to phylum Coelenterata [MP PMT 2002]  
(a) Sea pen (b) Sea feather  
(c) Sea cucumber (d) Sea fan
10. Sea anemone belongs to class [CPMT 1998]  
(a) Hydrozoa (b) Anthozoa  
(c) Scyphozoa (d) None of these
11. Primitive nervous system is formed in [CPMT 2009]  
(a) Sponge (b) Cnidaria (Coelenterata)  
(c) Echinodermata (d) Annelida
12. Corals belong to the phylum [MP PMT 1994]  
(a) Protozoa (b) Porifera  
(c) Cnidaria (d) Mollusca
13. The phylum of comb jelly is [NCERT; RPMT 1999]  
Or  
Which one of the following groups of animals reproduces only by sexual means [NEET (Karnataka) 2013]  
(a) Mollusca (b) Echinodermata  
(c) Coelenterata (d) Ctenophora
14. *Hydra* is [RPMT 1999, 2002]  
(a) Herbivorous (b) More developed  
(c) Carnivorous (d) Omnivorous
15. Polyp phase is absent in [BHU 2006]  
(a) *Hydra* (b) *Aurelia*  
(c) *Physalia* (d) *Obelia*
16. Jelly fish is placed in which class of coelenterata [RPMT 1995]  
(a) Anthozoa (b) Scyphozoa  
(c) Hydrozoa (d) None of the above
17. One of the special characters of coelenterata only is the occurrence of [CBSE PMT 1994; CPMT 1999; BHU 1999; MP PMT 2002, 06]  
(a) Hermaphroditism (b) Flame cells  
(c) Polymorphism (d) Nematocysts
18. Organ pipe coral is  
(a) *Astrea* (b) *Tubipora*  
(c) *Fungia* (d) *Meandrina*
19. Nematoblast of *Hydra* are [RPMT 2006]  
(a) Sensory  
(b) Complicated  
(c) With nematocyst apparatus  
(d) All of the above
20. The nitrogenous metabolic waste in *Hydra* mostly [AFMC 2006]  
(a) Ammonia and is removed from whole surface of body  
(b) Urea and is removed mainly by tentacles  
(c) Urea and is removed from whole surface of body  
(d) Uric acid and is removed from whole surface of body

21. A mature *Hydra* usually bears [CPMT 2002; RPMT 2005]  
 (a) One testis and several ovaries  
 (b) One testis and one ovary  
 (c) Several testes and one ovary  
 (d) Several testes and several ovaries
22. Main cavity in the body of *Hydra* is called [CPMT 1998]  
 (a) Gastrovascular cavity (b) Schizocoel  
 (c) Haemocoel (d) Pseudocoelom
23. Pneumatophore helps in [RPMT 1999]  
 (a) Feeding (b) Reproduction  
 (c) Protection (d) Floating
24. Which of the following statements is incorrect [CPMT 2010]  
 (a) Cnidocil is for defence in *Hydra*  
 (b) Nerve cells are absent in *Hydra*  
 (c) *Hydra* is a coelenterate  
 (d) *Hydra* shows budding
25. A coral island with a central shallow lake is known as [BHU 2001]  
 (a) Coral reef (b) Atoll  
 (c) Corallite (d) Diatomaceous sheath
26. Why does the Ctenophora is a minor phylum [RPMT 2001]  
 (a) It includes small sized animals  
 (b) It includes only few genera  
 (c) It does not include animals of economic importance  
 (d) It was included earlier in cnidaria
27. The larva of *hydra* is [RPMT 1999]  
 (a) Planula (b) Rhabditoid  
 (c) Trochophore (d) None of these
28. The true statement regarding corals is [AIIMS 1999]  
 (a) They form branched colonies  
 (b) Are solitary or colonial polypoid  
 (c) They grow as massive bodies  
 (d) All of these
29. *Hydra* is [CPMT 1993; RPMT 1999, 2000; Pb. PMT 2000; Odisha JEE 2012]  
 Or  
 Coelenterates generally include animals which are [CMC Vellore 1993]  
 (a) Triploblastic, radial symmetry and acoelomate  
 (b) Triploblastic, radial symmetry and coelomate  
 (c) Diploblastic, radial symmetry and acoelomate  
 (d) Diploblastic, radial symmetry and coelomate
30. Symmetry in Cnidaria is [CBSE PMT 2005]  
 (a) Radial (b) Bilateral  
 (c) Pentamerous (d) Spherical
31. How many ova are formed in the ovary of *hydra* [RPMT 1999]  
 (a) 2 (b) 4  
 (c) 1 (d) 3
32. Which one of the following animals is a coelenterate [MP PMT 2003; CPMT 2005]  
 (a) Sea cow (b) Sea horse  
 (c) Sea cucumber (d) Sea pen
33. *Hydra* receives impulses and stimuli through [CBSE PMT 2000; AIIMS 2002]  
 (a) Nerve net (b) Sensory cells  
 (c) Nematocytes (d) All of these
34. In which class of coelenterata the polyp and medusa both are found in one animal [RPMT 2001]  
 (a) Hydrozoa (b) Scyphozoa  
 (c) Anthozoa (d) None of them
35. Which of the following belongs to anthozoa [CPMT 1999]  
 (a) *Aurelia* (b) *Fungia*  
 (c) *Stercularia* (d) *Dugesia*
36. Match the following and choose the correct option  
 i. Physalia A. Sea anemone  
 ii. Meandrina B. Brain coral  
 iii. Gorgonia C. Sea fan  
 iv. Adamsia D. Portuguese man of war  
 [Bihar MDAT 1995; Kerala PMT 2002,12]  
 (a) i-C; ii-B; iii-A; iv-D (b) i-D; ii-C; iii-B; iv-A  
 (c) i-D; ii-B; iii-C; iv-A (d) i-B; ii-C; iii-A; iv-D  
 (e) i-A; ii-B; iii-C; iv-D
37. Statocysts are sense organs of [CPMT 1999]  
 (a) *Ascaris* (b) *Paramecium*  
 (c) *Taenia solium* (d) *Obelia medusa*
38. 'Ephyra' is the stage in the life cycle of [AFMC 2000, 09]  
 (a) Frog (b) *Obelia*  
 (c) *Aurelia* (d) Sea anemone
39. Choose the correct pair [MP PMT 2010; Kerala PMT 2012]  
 (a) Radial symmetry – Coelenterates  
 (b) Coelomates – Aschelminthes  
 (c) Metamerism – Molluscs  
 (d) Triploblastic – Sponges  
 (e) Metagenesis – Echinoderms
40. The characteristic larva of phylum 'Coelenterata' is [CPMT 2000; BHU 2006]  
 (a) Planula (b) Cysticercus  
 (c) Rhabdiform (d) Wriggler
41. Among the following organisms point out a completely non-parasitic form [CBSE PMT 1994]  
 (a) Sea anemone (b) Leech  
 (c) Tape worm (d) Mosquito
42. Which of the following is not found in vertebrates [MP PMT 1998]  
 (a) Bilateral symmetry (b) Gill opening  
 (c) Body scales (d) Cnidoblasts
43. In which phylum nerve cells are found but nerves are absent [RPMT 2001]  
 (a) Porifera (b) Coelenterata  
 (c) Platyhelminthes (d) Nematelminthes
44. Which of the following is not found in *Hydra* [DPMT 2004]  
 (a) Epithelio-muscular cells (b) Cnidocyte  
 (c) Choanocyte (d) Nerve cells
45. Which of the following animals has a nervous system but no brain [CBSE PMT 1993, 2002; BVP 2002]  
 (a) *Pheretima* (b) *Hydra*  
 (c) *Amoeba* (d) *Periplaneta*
46. Penetrant, valent and glutinant are types of  
 (a) Nematocysts of *Hydra* (b) Tentacles of *Hydra*  
 (c) Zooids of *Obelia* (d) Tentacles of *Obelia*

47. Tentacles of *Hydra* appear to be [Odisha JEE 2012]  
(a) 2 (b) 15  
(c) 8 (d) 14
48. The gastrovascular cavity of *Hydra* provides for  
(a) Digestion and storage (b) Storage and circulation  
(c) Excretion and storage (d) Digestion and circulation
49. Testes are located in *Hydra* at  
(a) Proximal half (b) Distal half  
(c) Middle (d) Tentacles
50. Zoochlorellae and zooxanthallae present in *Hydra* are [CPMT 1994; RPMT 1996]  
(a) Symbionts in nutritive cells  
(b) Symbionts in the gut  
(c) Symbionts in cnidoblasts  
(d) Organisms that provide hypnotoxin
51. Body cavity of *Hydra* is called [JIPMER 1998; Odisha JEE 2012]  
(a) Enterocoel (b) Coelenteron  
(c) Gastrovascular cavity (d) Both (b) and (c)
52. Precious Red Coral is/Coral used in ornaments is [MP PMT 1993]  
(a) *Astraea* (b) *Fungia*  
(c) *Corallium* (d) *Tubipora*
53. Gonads of *Obelia* occur  
(a) In hydrula stage and indefinite in number  
(b) Bases of tentacles of medusa and 8 in number  
(c) On blastostyles and 8 in number  
(d) On radial canals, oral surface of medusa and four in number
54. Gastrodermis of *Hydra* takes part in digestion of  
(a) Carbohydrates and fats  
(b) Proteins and fats  
(c) Proteins, fats and some carbohydrates  
(d) Proteins and carbohydrates
55. The cells absent in gastrodermis of *Hydra* are  
(a) Nutritive cells (b) Stinging cells  
(c) Gland cells (d) Nerve cells
56. Muscles of *Hydra* are  
(a) Smooth (b) Skeletal  
(c) Both (a) and (b) (d) None of the above
57. Budding is a normal mode of asexual reproduction in [CBSE PMT 1993; CPMT 1996; HP PMT 2005; Kerala PMT 2009; Odisha JEE 2009, 10]  
(a) Starfish and *Hydra* (b) *Hydra* and sponges  
(c) Tapeworm and *Hydra* (d) Sponges and starfish
58. Which of the following is not present in the body wall of *Hydra* [CPMT 2010]  
(a) Sensory cell (b) Glial cell  
(c) Cnidoblasts (d) Nerve cell
59. Nematocysts take part in [MP PMT 1993]  
(a) Locomotion (b) Offence and defence  
(c) Food capture (d) All the above
60. Which is wrongly matched [Odisha JEE 2004]  
(a) Euglenoidae → Myonemes (b) Ciliophora → Axonemes  
(c) Annelida → Notopodia (d) Cnidaria → Parapodia
61. Nematocysts are activated by [Bihar MDAT 1994]  
(a) Water (b) Touch  
(c) Brain (d) None of the above
62. Which one of the following living organisms completely lacks a cell wall [CBSE PMT 2014]  
(a) *Saccharomyces* (b) Blue-green algae  
(c) Cyanobacteria (d) Sea-fan (*Gorgonia*)
63. Which pair of cells is present in epidermis of *Hydra* but not in its endoderm [Bihar MDAT 1995]  
(a) Stinging cells and interstitial cells  
(b) Gland cells and germ cells  
(c) Stinging cells and germ cells  
(d) Stinging cells and gland cells
64. If *Hydra* is broken into pieces [RPMT 1995, 96; CPMT 1996]  
(a) *Hydra* will die  
(b) Every fragment will grow into complete *Hydra*  
(c) Some fragments will form complete  
(d) *Hydra* will undergo sexual reproduction
65. Testes/gonads are formed in *Hydra* from [RPMT 1995; Bihar MDAT 2001]  
(a) Interstitial cells (b) Epithelio-muscular cells  
(c) Nerve cells (d) All the above
66. Food of *Hydra* is [RPMT 1995]  
(a) Aquatic plants  
(b) Aquatic animals  
(c) Algae and aquatic animals  
(d) Some crustaceans
67. A number of buds have developed on *Hydra* [APMEE 1996; Pb. PMT 1999]  
(a) Oldest bud is towards oral region  
(b) Oldest bud is towards aboral region  
(c) Both (a) and (b)  
(d) There is no order
68. Mesogloea of *Hydra* is made of [RPMT 1996]  
(a) Mucopolysaccharides (b) Protein  
(c) Protein and fat (d) Reticulate tissue
69. Characteristic feature of coelenterata is [CPMT 1996]  
(a) All are marine  
(b) Presence of tentacles around mouth  
(c) Polyp  
(d) Gastrovascular cavity
70. Which of the following during respiration obtain water dissolved oxygen by diffusion through their body surface [HP PMT 2005]  
(a) Cnidarians (b) Fishes  
(c) Amphibians (d) Reptiles
71. *Hydra* recognises its prey by [BVP 2001; MHCET 2003]  
(a) Nematocyst (b) Chemical stimulus  
(c) Smell (d) Sensitivity
72. Common name of *Fungia* is [Bihar MDAT 1996]  
(a) Mushroom Coral (b) Red Coral  
(c) Brain Coral (d) Organ Pipe Coral

73. In *Hydra* new nematocysts develop from [BHU 1996]  
 (a) Cnidocils (b) Glandular cells  
 (c) Germ cells (d) Interstitial cells
74. Polymorphism occurs in [BHU 1997]  
 (a) Anthozoa (b) Scyphozoa  
 (c) Rhizopoda (d) Hydrozoa
75. Medusa of *Obelia* is [AIIMS 1999]  
 (a) Carnivorous (b) Herbivorous  
 (c) Detritus feeder (d) Omnivorous
76. Sense organs of *Aurelia* are [AIIMS 1999]  
 (a) Tentilla (b) Tentaculocyst  
 (c) Nematocyst (d) Otolith
77. Germ cells of *Hydra* are derived from [BHU 2000]  
 (a) Ectoderm (b) Endoderm  
 (c) Mesoderm (d) Mesogloea
78. Looping and somersaulting types of locomotion are seen in [Odisha JEE 2011]  
 (a) Leech (b) *Amoeba*  
 (c) Snail (d) *Hydra*

79. The figure shows four animals (A), (B), (C) and (D). Select the correct answer with respect to a common characteristics of two of these animals



[CBSE PMT (Mains) 2011]

- (a) (A) and (B) have cnidoblasts for self-defence  
 (b) (C) and (D) have a true coelom  
 (c) (A) and (D) respire mainly through body wall  
 (d) (B) and (C) show radial symmetry
80. In *Hydra*, cnidoblasts employed during looping are [APMEE 2000]  
 (a) Volvents (b) Stenoteles  
 (c) Atrichous isorhizas (d) Desmonemes
81. Animal showing thigmotaxis is [CPMT 2000]  
 (a) *Ascaris* (b) *Taenia*  
 (c) *Fungia* (d) *Hydra*
82. Which of the following symmetry is found in adult sea-anemone [CPMT 2004; Odisha JEE 2009]  
 (a) Biradial (b) Spherical  
 (c) Bilateral (d) None of these
83. Which is correct about nematocyst in *Hydra* [AFMC 2001]  
 (a) It is re-used  
 (b) Ejection is conditioned reflex  
 (c) Ejection occurs in response to contact and pierces the prey  
 (d) Prevents coming in contact with other *Hydra*

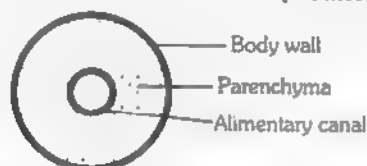
84. *Hydra* will regenerate from a fragment, if it contain [AFMC 2001]  
 (a) Tentacles  
 (b) Epidermis and gastrodermis  
 (c) Tentacles, epidermis and gastrodermis  
 (d) Epidermis, hypodermis and gastrodermis
85. Bilateral symmetry does not occur in [Pb. PMT 2001]  
 (a) Frog (b) *Octopus*  
 (c) Mammal (d) *Obelia*
86. Ctenophores have similarities with members [RPMT 2002]  
 (a) Porifera (b) Coelenterata  
 (c) Arthropoda (d) Annelida
87. Larva like stage of *Hydra* is [RPMT 2002]  
 (a) *Hydrula* (b) *Hydratuba*  
 (c) *Scyphula* (d) Planula

### Phylum-Platyhelminthes

1. Solenocytes and nephridia are respectively found in [RPMT 2002]  
 (a) Platyhelminthes and Annelids  
 (b) Annelids and Nematoda  
 (c) Cnidaria and Mollusca  
 (d) Mollusca and Echinodermata
2. Which of the following is a free living flat worm [NCERT; RPMT 2001; AMU (Med.) 2005]  
 (a) *Planaria* (b) *Taenia*  
 (c) *Fasciola* (d) *Pheretima*
3. In which of the following organisms, self fertilization is seen [KCET 2007; AFMC 2012]  
 (a) Fish (b) Roundworm  
 (c) Earthworm (d) Liver fluke
4. Which one of the following kinds of animals are triploblastic [AIIMS 2010; CBSE PMT (Pre.) 2010]  
 (a) Corals (b) Flat worms  
 (c) Sponges (d) Ctenophores
5. Cestodes are distinguished from other flatworms by the absence of [CPMT 2001]  
 (a) Nervous System (b) Digestive system  
 (c) Excretory system (d) Reproductive system
6. Which one of the following is an example of platyhelminthes [CBSE PMT 1994; AIIMS 1999]  
 (a) *Trypanosoma* (b) *Schistosoma*  
 (c) *Plasmodium* (d) *Wuchereria*
7. *Fasciola hepatica* is [AFMC 2008]  
 (a) Hermaphrodite, self fertilising  
 (b) Hermaphrodite, cross fertilising  
 (c) Unisexual  
 (d) Both (a) and (b)
8. Which of the following animals does not have a body composed of many segments [Odisha JEE 2009]  
 (a) Flatworm (b) Grass hopper  
 (c) Earthworm (d) Lobster
9. Cysticercus is the larva of [AFMC 2001; WB JEE 2010]  
 (a) Liver fluke (b) Tapeworm (*Taenia*)  
 (c) *Ascaris* (d) Mollusca
10. Planaria, liver fluke and taenia solium are [NCERT; CBSE PMT 1993]  
 (a) All segmented (b) All found in the gut  
 (c) All have coelom (d) All are flatworms



11. All flatworms differ from all roundworms in having [DUMET 2009]  
 (a) Triploblastic body  
 (b) Solid mesoderm  
 (c) Bilateral symmetry  
 (d) Metamorphosis in the life history
12. Which stage in the life cycle of *Taenia solium*, insects the intermediate host [EAMCET 2009]  
 (a) Hexacanth larva (b) Oncosphere  
 (c) Cysticercus larva (d) Miracidium
13. Flame cells are excretory organ of [JIPMER (Med.) 2002; J & K CET 2005; Manipal 2005; BHU 2005, 08; Odisha JEE 2012]  
 (a) Planaria (b) Flatworms  
 (c) *Taenia* (d) All of the above
14. Laurer's canal is found in [CPMT 1998; BHU 2012]  
 (a) Amoeba (b) Paramecium  
 (c) Fasciola (d) Hydra
15. Turbellarians are free living [CPMT 2000; BHU 2006]  
 (a) Nematodes (b) Annelids  
 (c) Trematodes (d) Flatworm
16. The cross-section of the body of an invertebrate is given below. Identify the animal which has this body plan [NCERT; KCET 2009]



- (a) Cockroach (b) Round worm  
 (c) Planaria (d) Earthworm
17. Locomotory organs in *Taenia* are called [AIIMS 2001; MH CET 2002]  
 (a) Setae (b) Parapodia  
 (c) Flagella (d) None of these
18. To which of the following Phylum class Trematoda belongs [MP PMT 2001]  
 (a) Platyhelminthes (b) Arthropoda  
 (c) Mollusca (d) Annelida
19. Identify the phylum X [KCET 2015]
- ANIMALIA

↓

TISSUE GRADE

↓

BILATERAL

↓

ACOELOMATE

↓

X
- (a) Hemichordata (b) Aschelminthes  
 (c) Platyhelminthes (d) Ctenophora
20. Flatworms are [EAMCET 1998]  
 (a) Acoelomates (b) Pseudocoelomates  
 (c) Haemocoelomates (d) Coelomates
21. Rhabdites occur in [AIIMS 1999; RPMT 2000]  
 (a) *Planaria/Dugesia* (b) *Fasciola*  
 (c) *Taenia* (d) *Echinococcus*
22. "Triploblastic, unsegmented, acoelomate exhibiting bilateral symmetry and reproducing both asexually and sexually with parasitic forms." The above description is characteristic of phylum [Kerala CET 2005; MP PMT 2011]  
 (a) Platyhelminthes (b) Annelida  
 (c) Ctenophora (d) Cnidaria  
 (e) Porifera
23. The contrast to Annelids the Platyhelminthes show [CBSE PMT 2005]  
 (a) Absence of body cavity (b) Bilateral symmetry  
 (c) Radial symmetry (d) Presence of pseudocoel
24. The greatest ability of regeneration amongst the animals is found in [HP PMT 2005; Kerala PMT 2010; CBSE PMT 2014]  
 (a) *Ascaris* (b) *Pheretima*  
 (c) *Hirudinia* (d) *Planaria* (Dugesia)
25. A metazoan covered by cilia is [APMEE 2000]  
 (a) *Paramecium* (b) *Dugesia*  
 (c) *Fasciola* (d) *Ascaris*
26. Chloragogen cells resemble the following in function [Manipal 2005]  
 (a) Collared cells (b) Flame cells  
 (c) Plasma cells (d) Mesophyll cells
27. Pseudocoelom is not found in [DPMT 2004]  
 (a) *Ascaris* (b) *Ancylostoma*  
 (c) *Fasciola* (d) None of these
28. One example of animals having a single opening to the outside that serves both as mouth as well as anus is [CBSE PMT (Pre.) 2010]  
 (a) *Fasciola* (b) Octopus  
 (c) *Asterias* (d) *Ascidia*
29. Which of the following show anaerobic respiration [MP PMT 2006]  
 (a) Earthworms (b) Rabbit  
 (c) Echinoderms (d) Tapeworms
30. Bilaterally symmetrical but acoelomate animal is [DPMT 2003; BVP 2004]  
 (a) Liver fluke (b) Jelly fish  
 (c) Round worms (d) Crab
31. Sometimes parasites themselves are parasitised by other organism, such parasites known as [AFMC 2003]  
 (a) Symbionts (b) Endoparasites  
 (c) Ectoparasites (d) Hyperparasites
32. Mehlis's glands of Tapeworm are associated with [BHU 2002]  
 (a) Reproduction (b) Excretion  
 (c) Respiration (d) Circulation
33. Malpighian tubules are analogous to [AFMC 2010]  
 (a) Trachea of cockroach (b) Gills  
 (c) Flame cells (d) None of these
34. Tapeworm does not possess digestive system as it [BHU 1994]  
 (a) Does not require solid food  
 (b) Obtains food through general surface  
 (c) Does not require food  
 (d) Lives in intestine

35. Intermediate host of Liver Fluke is  
(a) Pig (b) Man  
(c) Snail (d) Mosquito
36. The embryo of *Taenia* present in ripe proglottids is  
(a) Tetraacanth (b) Hexacanth  
(c) Miracidium (d) Bladderworm
37. *Schistosoma* is a parasite found in  
(a) Blood (b) Liver  
(c) Lungs (d) Intestine
38. Onchosphere occurs in [CBSE PMT 1990]  
(a) *Ascaris* (b) *Fasciola*  
(c) *Taenia* (d) *Planaria*
39. *Hymenolepis nana* is [APMEE 2001]  
(a) Dog Tapeworm (b) Dwarf Tapeworm of Man  
(c) Pork Tapeworm (d) Dead Man's Finger
40. *Fasciola hepatica* lives in [AFMC 2000; BHU 2001]  
(a) Liver of sheep (b) Blood of sheep  
(c) Intestine of sheep (d) Spleen of sheep
41. The intermediate host of *Schistosoma* is [BHU 2006]  
(a) Snail (b) Mosquito  
(c) Housefly (d) Sheep
42. Larva of *Schistosoma* is  
(a) Cercaria (b) Planula  
(c) Cysticercus (d) Muller's larva
43. What is correct about *Taenia*  
[CBSE PMT 1992; RPMT 1995, 98]  
(a) The animal has no mouth, alimentary canal and anus  
(b) Presence of hooks for adhesion, externally divided body  
(c) Mature proglottids contain both male and female organs  
(d) All of the above
44. What is true about *Taenia saginata* [CBSE PMT 1993]  
(a) Life history has pig as intermediate host  
(b) There are two large suckers on scolex  
(c) Rostellar hooks are absent  
(d) Rostellum has double circle of hooks
45. Cysticercus of *Taenia* develop in [AFMC 2001]  
(a) Man (b) Goat  
(c) Sheep (d) Pig
46. Which constitutes the correct pairing [CPMT 1994]  
(a) Flatworm-Planaria (b) Dogfish-Sea Urchin  
(c) Fish-Snail (d) None of the above
47. Anus is absent in [BHU 1994]  
(a) *Fasciola* (b) *Pheretima*  
(c) *Periplaneta* (d) *Unio*
48. Pick up the correctly matched [BHU 1994]  
(a) Water vascular system-Sponge  
(b) Blubber-Kangaroo  
(c) Marsupium-Platypus  
(d) Flame cell-Flatworm
49. Cysticerci in pig muscles can remain viable upto [AFMC 1994]  
(a) One year (b) Six months  
(c) Six years (d) One month
50. In life history of liver fluke are present (1) Cercaria (2) Metacercaria (3) Sporocyst (4) Redia (5) Miracidium. What is their proper sequence [AIIMS 1999]  
(a) 21354 (b) 53412  
(c) 54213 (d) 54312
51. Both alternation of generations and alternation of hosts are present in [APMEE 1995; BVP 2001]  
(a) *Wuchereria* (b) *Fasciola*  
(c) *Taenia* (d) *Ascaris*
52. Give the correct match in the following
- |    | Column I       |    | Column II       |
|----|----------------|----|-----------------|
| A. | Flame Cells    | p. | Sponges         |
| B. | Collar Cells   | q. | <i>Hydra</i>    |
| C. | Stinging Cells | r. | <i>Planaria</i> |
| -  | -              | s. | <i>Ascaris</i>  |
- [KCET 1997]  
(a) A = r, B = p, C = q (b) A = r, B = p, C = s  
(c) A = r, B = s, C = p (d) A = r, B = q, C = s
53. Solenocytes/flame cells are excretory structures of [AFMC 1997; CBSE PMT 1998; CPMT 1998; DPMT 2006]  
(a) Echinoderms (b) Annelids  
(c) Platyhelminthes (d) Molluscs
54. Lung Fluke is [APMEE 2002]  
(a) *Hymenolepis nana*  
(b) *Paragonimus westermani*  
(c) *Schistosoma haematobium*  
(d) *Echinococcus granulosus*
55. Alimentary canal is absent in [RPMT 1998; CPMT 1999; JIPMER (Med.) 2001, 02; J & K CET 2002]  
(a) *Taenia* and *Schistosoma* (b) *Ascaris* and *Fasciola*  
(c) *Taenia* and *Echinococcus* (d) *Tricuris* and *Fasciola*

### Phylum-Nemathelminthes

1. Pin worm is called as [EAMCET 1998; BHU 2012; MP PMT 2013]  
(a) *Schistosoma haematobium*  
(b) *Wuchereria bancrofti*  
(c) *Ancylostoma duodenale*  
(d) *Enterobius vermicularis*
2. Pineal setae in male *Ascaris* are found in [RPMT 1999]  
(a) Cloaca (b) Rectum  
(c) Anus (d) Mouth
3. Which one of the following groups of animals is bilaterally symmetrical and triploblastic [CBSE PMT 2009]  
(a) Coelenterates (Cnidarians)  
(b) Aschelminthes (round worms)  
(c) Ctenophores  
(d) Sponges
4. The parasite which completes its life cycle in a single host (only man) is [RPMT 1999; WB JEE 2008]  
(a) *Fasciola hepatica* (b) *Plasmodium vivax*  
(c) *Taenia solium* (d) *Ascaris lumbricoides*
5. Which of the following groups have one or more animals which are not pseudocoelomate [AFMC 1993]  
(a) *Ascaris*, *taenia*  
(b) *Enterobius*, *wuchereria*  
(c) *Ancylostoma*, *dracunculus*  
(d) *Ascaris*, *ancylostoma*
6. *Ancylostoma* infection spreads through [AFMC 2001]  
(a) Contaminated food (b) Kissing  
(c) Skin (d) Blood

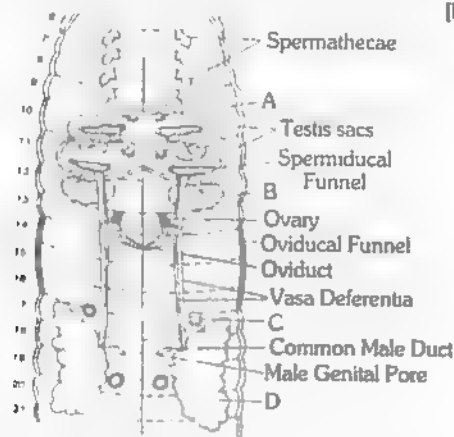
7. In *Ascaris* 3rd moulting takes place in [CPMT 2002; RPMT 2005]
  - (a) Intestine (b) Lung
  - (c) Liver (d) Egg
8. Excretory pore of *Ascaris* is present [CPMT 2010]
  - (a) Behind the mouth (b) On the posterior end
  - (c) On the dorsal side (d) In the middle of the body
9. A rhabditiform larva is formed in the life cycle of [CPMT 1998; RPMT 2001]
  - (a) *Ascaris* (b) Tapeworm
  - (c) *Hydra* (d) *Leucosolenia*
10. Choose the correct statement with reference to *Ascaris* [CPMT 2004]
  - (a) Hatching of embryos takes place in the stomach due to lytic enzyme
  - (b) Adulthood is reached inside the body of the host in ten days time
  - (c) Development and moulting takes place in the alveoli of lungs
  - (d) Hatching of embryo takes places within ten hours
11. In nemathelminthes the coelom is not lined by peritoneum is [AFMC 2004]
  - (a) A coelom (b) Pseudocoelom
  - (c) Enterocoelom (d) Haemocoel
12. Which of the following sense organs present in *Ascaris* are chemoreceptors and are located in ventrolateral lips [CPMT 1999]
  - (a) Amphids (b) Pineal setae
  - (c) Pineal spicules (d) Copulatory bursa
13. One of the following is pseudocoelomate [DPMT 2001]
  - (a) Leech (b) Liver fluke
  - (c) Hookworm (d) Jelly fish
14. *Ascaris* performs [RPMT 1999]
  - (a) Aerobic respiration (b) Anaerobic respiration
  - (c) Both (a) and (b) (d) None of these
15. Filariform is larva of [AFMC 2001]
  - (a) Platyhelminthes (b) Aschelminthes
  - (c) Annelids (d) Arthropods
16. Thigmotaxis is not shown by [BHU 2006]
  - (a) *Paramecium* (b) *Amoeba*
  - (c) *Ascaris* (d) *Hydra*
17. The adult *Wuchereria bancrofti* lives in or attacks [EAMCET 1998; AIIMS 2000, 02; CPMT 2009; NEET (Karnataka) 2013]
  - (a) Human subdermal spaces
  - (b) Muscles of culex
  - (c) Salivary glands of culex
  - (d) Human lymph glands
18. Musculature of *Ascaris* consists of
  - (a) Circular muscles only
  - (b) Outer longitudinal and inner circular
  - (c) Outer circular and inner longitudinal
  - (d) Longitudinal muscles only
19. Which is the monogenetic in following [AFMC 2003]
  - (a) Tapeworm (b) *Ascaris*
  - (c) *Fasciola* (d) Hookworm
20. All worms are [MP PMT 2003]
  - (a) Triploblastic (b) Segmented
  - (c) Endo-parasites (d) Free-living
21. Which of the following is metazoan parasite transmitted through contaminated food or water [APMEE 1995; DPMT 1999; MH CET 2000]
  - (a) *Ascaris* (b) *Entamoeba*
  - (c) Guinea worm (d) Worm
22. The anterior V – spot in microfilaria of *Wuchereria* represents [WB JEE 2011]
  - (a) Nerve ring (b) Cervical papilla
  - (c) Excretory system (d) Reproductive system
23. Syncytial epidermis occurs in [BHU 1994, 2001; DPMT 1999, 2001; Bihar MDAT 2002; CBSE PMT 2002]
  - (a) *Ascaris* (b) *Hydra*
  - (c) *Taenia* (d) *Leucosolenia*
24. Male *Ascaris* is differentiable from female *Ascaris* in
  - (a) Presence of post-anal papillae
  - (b) Presence of pre-anal papillae
  - (c) Presence of penial setae
  - (d) All the above
25. Female *Ascaris* is differentiable from male in
  - (a) Presence of cloaca (b) Presence of penial setae
  - (c) Shorter size (d) Straight posterior end
26. *Ascaris* is characterized by [CBSE PMT 2008]
  - (a) Presence of true coelom but absence of metamerism
  - (b) Presence of true coelom and metamerism (metamerisation)
  - (c) Absence of true coelom but presence of metamerism
  - (d) Presence of neither true coelom nor metamerism
27. An intermediate host is absent in case of parasite
  - (a) Liver fluke (b) Tapeworm
  - (c) *Ascaris* (d) *Plasmodium*
28. *Ascaris* protects itself against digestive enzymes of the host by
  - (a) Mucus (b) Antienzymes
  - (c) Antienzymes and cuticle (d) Cuticle
29. Which is true of *Ascaris*
  - (a) Host (b) Aquatic
  - (c) Unisexual (d) Bisexual
30. Alcopar is drug useful for
  - (a) Taeniasis (b) Amoebiasis
  - (c) Ascariasis (d) Schistosomiasis
31. *Cyclops* is intermediate host of [HPMT 1993]
  - (a) *Planaria/Dugesia* (b) *Echinococcus*
  - (c) *Dracunculus* (d) *Ancylostoma*
32. Differentiating trait of *Ascaris* is [RPMT 2002]
  - (a) Sexual dimorphism and rhabditiform larva
  - (b) Unisexual and digenetic parasite
  - (c) Pseudocoelom and metameric segmentation
  - (d) Hermaphrodite and pseudocoelom
33. Microfilariae are carried by [CPMT 1993]
  - (a) Sandfly (b) *Culex* mosquito
  - (c) *Anopheles* mosquito (d) Housefly

34. The first and last moults of *Ascaris* occur in [CPMT 1993]  
Or  
Fourth moulting of *Ascaris* occur in [Odisha JEE 2012]  
(a) Heart (b) Kindey  
(c) Liver (d) Intestine
35. Which one is used in treatment of ascariasis [CPMT 1994]  
(a) Chenopodium oil (b) Paludrin  
(c) Terramycin (d) None of the above
36. A thick layer of cuticle on the surface of *Ascaris* indicates [CPMT 1994]  
(a) Reproduction (b) Growth  
(c) Parasitism (d) Evolution
37. Embryonated egg of *Ascaris* is [BHU 1994]  
(a) An egg with gastrula (b) An egg with blastula  
(c) An egg with juvenile (d) An egg within an egg
38. Sensory structures in *Ascaris* are [RPMT 1995]  
(a) Phasmids (b) Amphids  
(c) Papillae (d) All the above
39. Excretory pores present in *Ascaris* are [RPMT 1995]  
(a) One (b) Two  
(c) One pair (d) Two pairs
40. *Ascaris lumbricoides* is commonly called [Kerala PMT 2002]  
(a) Roundworm (b) Hookworm  
(c) Seat worm (d) Pinworm  
(e) Filarial worm
41. Pseudocoelom develop from [CPMT 2002]  
(a) Blastopore lip (b) Archenteron  
(c) Embryonic mesoderm (d) Blastocoel
42. Which is secondary/intermediate host of Hookworm [Bihar MDAT 1995]  
(a) Bed Bug (b) Sandfly  
(c) Mosquito (d) None of the above
43. *Wuchereria* causes a disease in parts of India [BHU 1996]  
(a) Filariasis-South India (b) Elephantiasis-Bihar  
(c) Elephantiasis-Karnataka (d) None of the above
44. Which larval stage of *Ascaris* is infective [RPMT 1996]  
(a) First and fourth (b) Second and third  
(c) First and second (d) Third and fourth
45. Which is not true of *Ascaris* infection [RPMT 1996]  
(a) More common in children  
(b) Does not produce tonsilitis  
(c) Number can be 500-5000  
(d) Infection is cured even without medication
46. Life span of *Ascaris* is [RPMT 1996; AFMC 2010]  
(a) 6-9 months (b) 9-12 months  
(c) 4-10 months (d) 10-12 months
47. *Ascaris* has three lips [APMEE 1996; Odisha JEE 2012]  
(a) One median dorsal and two ventrolateral  
(b) All dorsal  
(c) Two lateral and one ventral  
(d) Two dorso-lateral and one median ventral
48. Number of juvenile stages found during development of *Ascaris* [RPMT 1998]  
(a) 1 (b) 2  
(c) 3 (d) 4
49. *Enterobius* infection occurs through [Pb. PMT 1999]  
(a) Mosquito (b) Contamination  
(c) Inoculation (d) Piercing
50. *Microfilaria* occurs in peripheral blood of human beings during [Pb. PMT 1999]  
(a) Morning (b) Evening  
(c) Night (d) Day time
51. Animal group with pseudocoelom is [MP PMT 2001; CPMT 2002; Kerala PMT 2002, 10; DPMT 2002, 06; Odisha JEE 2004; RPMT 2005]  
(a) Echinoderms  
(b) Molluscs  
(c) Aschelminthes/Nematodes  
(d) Annelids
52. Which one of the following statements about certain given animals is correct [BHU 2006, 12; AMU (Med.) 2006; CBSE PMT (Pre.) 2010]  
(a) Flat worms (Platyhelminthes) are coelomates  
(b) Round worms (Aschelminthes) are pseudocoelomates  
(c) Molluscs are acoelomates  
(d) Insects are pseudocoelomates
53. Coenocytic condition is found in [HP PMT 2005]  
(a) *Ulothrix* (b) *Chlamydomonas*  
(c) *Spirogyra* (d) *Wuchereria*
54. Size of female *Ascaris lumbricoides* is [RPMT 2000]  
(a) 50-80 mm (b) 100-150 mm  
(c) 150-250 mm (d) 200-350 mm
55. An ovoviviparous parasite is [APMEE 2001]  
(a) *Taenia* (b) *Wuchereria*  
(c) *Ascaris* (d) *Plasmodium*
56. Larvae of *Ascaris* hatch out in [CPMT 2001]  
(a) Soil (b) Intestine  
(c) Liver (d) Lungs

### Phylum-Annelida

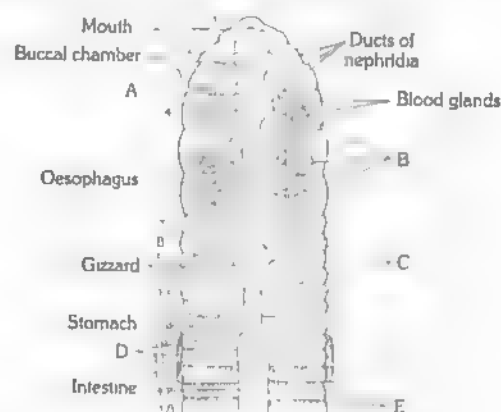
1. Which one of the following correctly describes the location of some body parts in the earthworm *Pheretima* [CPMT 1994; Odisha JEE 1997; CBSE PMT 2009]  
(a) Two pairs of accessory glands in 16-18 segments  
(b) Four pairs of spermathecae in 4-7 segments  
(c) One pair of ovaries attached at intersegmental septum of 14<sup>th</sup> and 15<sup>th</sup> segments  
(d) Two pairs of testes in 10<sup>th</sup> and 11<sup>th</sup> segments
2. If a live earthworm is pricked with a needle on its outer surface damaging its gut, the fluid that comes out is [CBSE PMT 2009]  
Or  
Earthworms have no skeleton but during burrowing, the anterior end becomes turgid and acts as a hydraulic skeleton. It is due to [CBSE PMT 2008]  
(a) Excretory fluid (b) Coelomic fluid  
(c) Haemolymph (d) Slimy mucus
3. Male genital aperture of earthworms is located in the segment [NCERT; CPMT 1999]  
(a) 13 (b) 14  
(c) 19 (d) 18

4. Annelids are [CMC Vellore 1993]  
(a) Radially symmetrical (b) Externally segmented  
(c) Triploblastic (d) Pseudocoelomate
5. The parasite found in the seminal vesicle of earthworm [RPMT 1999, 2006]  
(a) *Monocystis* (b) *Nosema*  
(c) *Sarcocystis* (d) *Nyctotherus*
6. Which one of the following is NOT a characteristic of phylum Annelida [DPMT 2003; BVP 2004; CBSE PMT 2008]  
(a) Pseudocoelom (b) Ventral nerve cord  
(c) Closed circulatory system (d) Segmentation
7. Which one of the following is not hermaphrodite animal [HP PMT 2005; Odisha JEE 2008]  
(a) Leeches (b) Polychaetes  
(c) Flatworms (d) Earthworm
8. *Pheretima posthuma* and *Periplaneta* are similar in which aspect [CPMT 1995]  
(a) Both have nephridia as excretory organs  
(b) Both have ventral nerve cord  
(c) Both belong to same taxonomical group  
(d) All the above
9. Which of the following belongs to the phylum annelida [Odisha JEE 1997]  
(a) Octopus (b) Ant  
(c) Nerela (d) Crab
10. Specialized chemoreceptors located on the anterior part of earthworms are [Kerala PMT 2012]  
(a) Heat receptors (b) Photo receptors  
(c) Taste receptors (d) Pressure receptors  
(e) Auditory receptors
11. Closed blood vascular system, liver cells in the blood and chitinous setae or parapodia are the characteristics of [AFMC 2009]  
(a) Arthropoda (b) Nematoda  
(c) Annelida (d) None of these
12. See the figure given below and identify A to D respectively [NCERT]



- (a) A – Seminal vesicle, B – Testis, C – Prostate gland, D – Accessory gland  
(b) A – Testis, B – Seminal vesicle, C – Prostate gland, D – Accessory gland  
(c) A – Seminal vesicle, B – Testis, C – Accessory gland, D – Prostate gland  
(d) A – Testis, B – Seminal vesicle, C – Accessory gland, D – Prostate gland

13. In which of the following, clitellum is absent [BHU 2000]  
(a) Polychaeta (b) Oligochaeta  
(c) Hirudinea (d) All the above
14. One very special feature in the earthworm pheretima is that [NCERT; AFMC 1999; CBSE PMT (Pre.) 2011]  
(a) It has a long dorsal tubular heart  
(b) Fertilisation of eggs occurs inside the body  
(c) The typhlosole greatly increases the effective absorption area of the digested food in the intestine  
(d) The S-shaped setae embedded in the integument are the defensive weapons used against the enemies
15. Botryoidal tissue is found in [BHU 2002]  
(a) Rabbit (b) *Ascaris*  
(c) *Hirudinaria* (d) Earthworm
16. Identify the following structures labelled A to E in the diagram given below from the list I to V

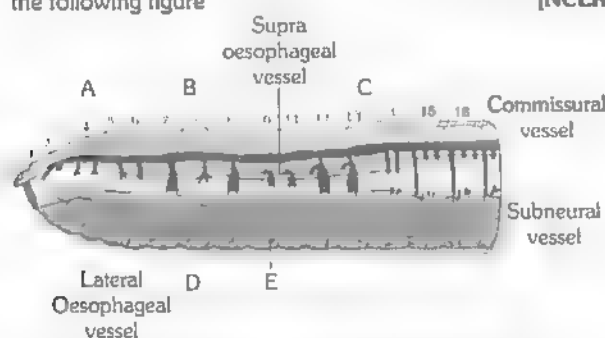


- I. Septal nephridia  
II. Pharynx  
III. Forest of integumentary nephridia  
IV. Integumentary nephridia  
V. Tufts of Pharyngeal nephridia

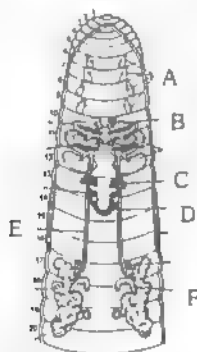
[NCERT]

	A	B	C	D	E
(a)	II	III	IV	I	V
(b)	II	IV	V	I	III
(c)	II	V	IV	III	I
(d)	II	I	III	IV	V

17. In *Pheretima*, there are red coloured round bodies in 4th, 5th and 6th segments above the alimentary canal. They are believed to be involved in [NCERT; BHU 1999]  
(a) Excretion (b) Digestion  
(c) Reproduction (d) Leucocyte production
18. Which one of the following exhibits concentric "tube within tube" plan [MP PMT 1999]  
(a) Arthropoda (b) Oligochaeta  
(c) Mollusca (d) Echinodermata
19. The colour of the body in earthworm is brown due to the presence of [CPMT 2001]  
(a) Porphyrin (b) Haemoglobin  
(c) Blood (d) Haemocyanin

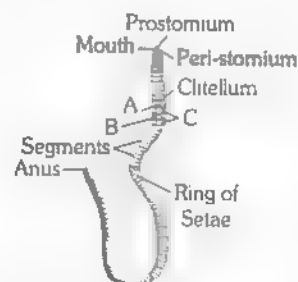
20. The famous Indian Zoologist who wrote a memoir upon *Pheretima posthuma* is [CBSE PMT 2001]  
(a) J.C. Bose (b) M.L. Bhatia  
(c) K.N. Bahl (d) Beni Prasad
21. The highly degraded organic matter rich in nitrogen and potassium in particular, resulting from the activity of earthworms, is called [NCERT; KCET 2006]  
(a) Worm castings (b) Vermicompost  
(c) Compost bedding (d) Humus
22. In which of the following class of Annelida, one pair ovaries and several pair testes are found [MP PMT 2003]  
(a) Archiannelida (b) Hirudinea  
(c) Oligochaeta (d) Polychaeta
23. Which one of the following pairs of items correctly belongs to the category of organs mentioned against it [CBSE PMT 2008]  
(a) Nephridia of earthworm and malpighian tubules of Cockroach - Excretory organs  
(b) Wings of honey bee and wings of crow - Homologous organs  
(c) Thorn of Bougainvillea and tendrils of Cucurbita - Analogous organs  
(d) Nictitating membrane and blind spot in human eye - Vestigial organs
24. Aphrodite, commonly known as sea mouse is a [J & K CET 2008]  
(a) Annelid (b) Mollusca  
(c) Insect (d) Mammal
25. Observe the blood vascular system of earthworm given in the following figure [NCERT]
- 
- |     | A              | B              | C                             | D              | E                             |
|-----|----------------|----------------|-------------------------------|----------------|-------------------------------|
| (a) | Ventral vessel | Lateral hearts | Anterior loop                 | Dorsal vessel  | Lateral-oesopharyngeal hearts |
| (b) | Dorsal vessel  | Lateral hearts | Anterior loop                 | Ventral vessel | Lateral-oesopharyngeal hearts |
| (c) | Ventral vessel | Lateral hearts | Lateral-oesopharyngeal hearts | Dorsal vessel  | Anterior loop                 |
| (d) | Dorsal vessel  | Lateral hearts | Lateral-oesopharyngeal hearts | Ventral vessel | Anterior loop                 |
26. The two organisms which breathe only through their moist skin are [Odisha JEE 2009; J & K CET 2012]  
(a) Fish and frog (b) Frog and earthworm  
(c) Leech and earthworm (d) Fish and earthworm
27. Earthworms are [CBSE PMT 2006]  
(a) Uricotelic under conditions of water scarcity  
(b) Ammonotelic when plenty of water is available  
(c) Ureotelic when plenty of water is available  
(d) Uricotelic when plenty of water is available
28. In the 4<sup>th</sup>, 5<sup>th</sup> and 6<sup>th</sup> segments of earthworm, lying above pharyngeal mass and connected with pharyngeal glands are found small, red coloured follicular bodies called [NCERT; APMEE 2002; Kerala PMT 2006]  
(a) Septal glands (b) Blood glands  
(c) Salivary glands (d) Nephridia  
(e) Intestinal caecae
29. Region of Earthworm which is forest of nephridia is [NCERT; CPMT 2002]  
(a) Clitellar region (b) Pharyngeal region  
(c) Typhlosolar region (d) Intestinal region
30. Chloragogen cells are present in [RPMT 1998]  
(a) Body wall of *Leucosolenia*  
(b) Blood of Earthworm  
(c) Coelomic fluid of Earthworm  
(d) Blood of Cockroach
31. Leech is [J & K CET 2005]  
(a) Carnivorous (b) Sanguivorous  
(c) Ectoparasite (d) Both (b) and (c)
32. In Earthworm, genital papillae occur in segments [NCERT]  
(a) 16 and 17 (b) 16 and 18  
(c) 17 and 19 (d) 17 and 18
33. Flow of blood in dorsal blood vessel of Earthworm is  
(a) Backward (b) Forward  
(c) Sideward (d) Downward
34. The lateral hearts in earthworm have [NCERT; AMU (Med.) 2010]  
(a) Four pairs of valves and are situated in segments 7 and 9  
(b) Four pairs of valves and are situated in segments 6 and 8  
(c) Three pairs of valves and are situated in segments 8 and 10  
(d) Two pairs of valves and are situated in segments 6 and 11
35. The female genital aperture in earthworm is present ventrally on the segment [NCERT; CPMT 2000; BHU 2006]  
(a) 10th (b) 12th  
(c) 14th (d) 18th
36. In earthworm, the characteristic internal median fold of dorsal wall of the intestine called typhlosole is present in [Kerala PMT 2008]  
(a) 5 to 9 segments (b) 9 to 14 segments  
(c) 26 to 35 segments (d) 15 to last segment  
(e) 35 to last segment
37. Hearts of *Pheretima* are situated in the segments [NCERT]  
(a) 10, 13, 16 and 17 (b) 7, 9, 12 and 13  
(c) 4, 5, 10 and 13 (d) 11, 14, 17 and 18

38. In earthworm fertilization occurs in [NCERT; CPMT 2005; Bihar CECE 2006]  
 (a) Oviduct (b) Spermatheca  
 (c) Clitellum (d) Cocoon
39. The main function of clitellum is [RPMT 2002; BCECE 2005]  
 (a) Cocoon formation (b) Locomotion  
 (c) Excretion (d) Copulation
40. Pheretima is [NCERT]  
 (a) Sterile (b) Hermaphrodite  
 (c) Radially symmetrical (d) Dioecious
41. In *Pheretima*, gizzard, buccal cavity, pharynx, oesophagus, pharyngeal nephridia receive the blood from this blood vessel [EAMCET 2009]  
 (a) Supra oesophageal (b) Lateral oesophageal  
 (c) Dorsal Blood (d) Subneural
42. Major nitrogenous excretory material of Earthworm is  
 (a) Uric acid (b) Ammonia  
 (c) Urea (d) Amino acids
43. Occurrence of Earthworm in soil is indicated by  
 (a) Heaps of small rounded pellets  
 (b) Heaps of dry powder soil  
 (c) Holes  
 (d) Cast skin
44. Clitellum of *Pheretima* is thick girdle that is [NCERT; BHU 1996; MHCET 2003; AFMC 2010]  
 (a) Nonglandular around 14-16 segments  
 (b) Glandular around 14-16 segments  
 (c) Glandular around 16-18 segments  
 (d) Nonglandular around 16-18 segments
45. The location of lymph glands in *Pheretima* is [NCERT; EAMCET 2009]  
 (a) 4<sup>th</sup>, 5<sup>th</sup> and 6<sup>th</sup> segments (b) 10<sup>th</sup> to 20<sup>th</sup> segments  
 (c) 26<sup>th</sup> to the last segments (d) 13<sup>th</sup> segment
46. Trochophore larva is found in [CPMT 2005]  
 (a) *Chiton* (b) *Nereis*  
 (c) *Aphrodite* (d) All of these
47. Choose the correct combination of labelling from the options given [NCERT; Kerala PMT 2009, 11]



- (a) A – testis, B – spermatheca, C – seminal vesicle, D – ovary, E – vas deferens, F – accessory gland  
 (b) A – spermatheca, B – testis, C – ovary, D – seminal vesicle, E – vas deferens, F – accessory gland  
 (c) A – spermatheca, B – testis, C – seminal vesicle, D – ovary, E – vas deferens, F – accessory gland  
 (d) A – spermatheca, B – testis, C – accessory gland, D – ovary, E – vas deferens, F – seminal vesicle  
 (e) A – spermatheca, B – ovary, C – seminal vesicle, D – testis, E – vas deferens, F – accessory gland

48. Earthworm has [NCERT]  
 (a) Two eyes (b) Many eyes  
 (c) No eyes (d) One eyes
49. Photoreceptors of Earthworm occur on  
 (a) Clitellum (b) Anal segment  
 (c) Dorsal surface (d) Lateral sides
50. Examine the ventral view of earthworm and identify A, B and C [NCERT]



	A	B	C
(a)	Female genital pore	Male genital pore	Genital papilla
(b)	Female genital pore	Genital papilla	Male genital pore
(c)	Male genital pore	Female genital pore	Genital papilla
(d)	Excretory pore	Female genital pore	Male genital pore

51. *Pheretima posthuma* (earthworm) is highly useful as [NCERT]

Or

Most important use of earthworm is

[CBSE PMT 1990; AFMC 2000]

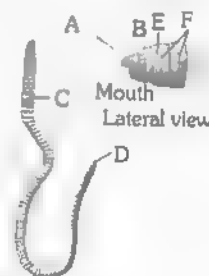
- (a) Their burrows make the soil loose  
 (b) They make the soil porous, leave their castings and take organic debris in the soil  
 (c) They are used as fish meal  
 (d) They kill the birds due to biomagnification of chlorinated hydrocarbons

52. Earthworm possesses hearts [NCERT; CBSE PMT 1991; RPMT 2000; AFMC 2006]  
 (a) 6 pairs (b) 4 pairs  
 (c) 2 pairs (d) 1
53. The septal and pharyngeal nephridia open into alimentary canal and are of enteronephric type. It is an adaptation for [NCERT; CPMT 1993; MP PMT 2004; AMU (Med) 2009]  
 (a) Conservation of water (b) Conservation of heat  
 (c) Regulation of temperature (d) Regulation of amino acids
54. In earthworm, gizzard is found in [CPMT 2009]  
 (a) 8 – 10 Segment (b) 8<sup>th</sup> segment  
 (c) 27<sup>th</sup> segment (d) 8 – 11 segment
55. In earthworm, ovary is situated in segment [NCERT; AFMC 1993; AIIMS 1993; BHU 2012]  
 (a) 13 (b) 9  
 (c) 10 (d) 26

56. Blood of *Pheretima* is [NCERT; CBSE PMT 1990; Odisha JEE 2005]  
 (a) Blue with haemocyanin in corpuscles  
 (b) Blue with haemocyanin in plasma  
 (c) Red with haemoglobin in corpuscles  
 (d) Red with haemoglobin in plasma.
57. Suctorial mouth occurs in [AFMC 2000]  
 (a) Butterfly (b) Leech  
 (c) *Taenia* (d) Cockroach
58. The animal which does not show any metamorphosis of larval stage is [Pb. PMT 1997]  
 (a) *Pheretima posthuma* (b) Asterial  
 (c) *Musca domestica* (d) Butterfly
59. Which one of the following groups of structures/organs have similar function [AIIMS 2005]  
 (a) Typhlosole in earthworm, intestinal villi in rat and contractile vacuole in *Amoeba*  
 (b) Nephridia in earthworm, Malpighian tubules in cockroach and urinary tubules in rat  
 (c) Antennae of cockroach, tympanum of frog and clitellum of earthworm  
 (d) Incisors of rat, gizzard (proventriculus) of cockroach and tube feet of starfish
60. Earthworms have how many segments [NCERT; HPMT 2005]  
 (a) 85 - 400 (b) 100 - 200  
 (c) 20 - 95 (d) 115 - 120
61. Specialised respiratory organs are absent in [CPMT 2000]  
 Or  
 In which of the following respiration occurs without any respiratory organ [BHU 2006]  
 (a) Mosquito larva (b) Tadpole  
 (c) Cockroach (d) Earthworm
62. Blood of Earthworm is red because its haemoglobin is [RPMT 1995]  
 (a) Intracellular (b) Intercellular  
 (c) Oxidised (d) Reduced
63. Earthworm found in India is [NCERT; RPMT 1995]  
 (a) *Lumbricus* (b) *Pheretima*  
 (c) *Drawida* (d) *Megascolex*
64. Which one assists in locomotion [CBSE PMT 1993; DPMT 1995]  
 (a) Trichocysts in *Paramecium*  
 (b) Pedicellariae of Star Fish  
 (c) Clitellum in *Pheretima*  
 (d) Posterior sucker in *Hirudinaria*
65. Trait common amongst Earthworm, Leech and Centipede is [CBSE PMT 1993]  
 (a) Absence of legs (b) Hermaphrodite nature  
 (c) Ventral nerve cord (d) Malpighian tubules
66. Leech secretes which of the following anticoagulant [AFMC 2005]  
 (a) Hirudin (b) Heparin  
 (c) Serotonin (d) Histamine
67. In Earthworm, arrangement of blood vessels is [BHU 1994, 2000, 01]  
 (a) Different in last fifteen segments  
 (b) Different in first thirteen segments  
 (c) Same throughout  
 (d) Different in middle thirteen segments
68. Chloragogen cells are involved in [RPMT 1995; APME 1995; DPMT 1999]  
 (a) Digestion (b) Excretion of water  
 (c) Respiration (d) Fat storage
69. Excretory organs of Earthworm are [NCERT; RPMT 1995; Manipal 1995, 99]  
 (a) Coelom (b) Flame cells  
 (c) Nephridia (d) Gizzard
70. Spermathecae in earthworm is [NCERT; AFMC 2005]  
 (a) For producing sperm  
 (b) For storage of sperm obtained from male earthworm during copulation and used in future  
 (c) Both (a) and (b)  
 (d) None of these
71. In Earthworm, the effective organ for food digestion is [RPMT 1995]  
 (a) Pharynx (b) Buccal cavity  
 (c) Mouth (d) Stomach
72. Life span of Earthworm is [RPMT 1996]  
 (a) 1 - 3 years (b) 2 - 8 years  
 (c) 3.5 - 10.5 years (d) 6 - 8 years
73. Copulation period of Earthworm is [APME 1996]  
 (a) One hour (b) Two hours  
 (c) Four hours (d) About one week
74. In *Pheretima* nephridia occur in [APME 1996]  
 (a) All segment except 1 - 4 and 10 - 14  
 (b) 1 - 2, 4 - 6, 15 to last segments  
 (c) Meganephridia in pre-clitellar and micronephridia in post-clitellar segments  
 (d) Micronephridia in all segments meganephridia from clitellar region to end
75. In Earthworm [APME 1996]  
 (a) Ovaries are larger than testes  
 (b) Testes are larger than ovaries  
 (c) Both are equal  
 (d) Right testes are larger the ovaries
76. Trochophore larva is found in [DPMT 2004]  
 (a) Annelida (b) Platyhelminthes  
 (c) Coelenterate (d) Prawn
77. Name the animal having both setae and nephridia [DPMT 1996]  
 (a) Sea Urchin (b) Sea Mouse  
 (c) Sea Anemone (d) Sea Pen
78. Spermathecal pores of *Pheretima* are present in [NCERT; CPMT 1996, 98; AMU (Med.) 2005; Kerala PMT 2010]  
 (a) 5/6, 6/7 7/8 and 8/9  
 (b) 6/7, 7/8 8/9 and 9/10  
 (c) 1/2, 2/3, 3/4 and 4/5  
 (d) 14/15, 15/16, 16/17 and 17/18
79. Typhlosole found in *Pheretima* occurs in [CPMT 1996]  
 (a) Oesophagus (b) Stomach  
 (c) Gizzard (d) Intestine



80. Chromophil cells present on pharynx of Earthworm take part in secretion of [RPM T 1996]  
(a) Mucus (b) Lipases  
(c) Carbohydrases (d) All the above
81. Nephrostome occurs in [RPM T 1998]  
(a) Septal nephridia  
(b) Integumentary nephridia  
(c) Pharyngeal and septal nephridia  
(d) Pharyngeal and integumentary nephridia
82. Animals having multiple or numerous setae are included under [RPM T 1998]  
(a) Polychaeta (b) Oligochaeta  
(c) Hirudinea (d) Onychophora
83. Movement of coelomic fluid helps in locomotion of [JIPMER 1999]  
(a) Hydra (b) Frog  
(c) Starfish (d) Earthworm
84. Which of the following annelids is a parasite on snails and frogs [MP PM T 2013]  
(a) Acanthobdella (b) Pontobdella  
(c) Branchellion (d) Glossiphonia
85. Which one is not deuterostome [AFMC 1999]  
(a) Chordata (b) Cephalochordata  
(c) Annelida (d) Echinodermata
86. In Earthworm, mouth is situated on [NCERT; APME E 1999]  
(a) Prostomium (b) Peristomium  
(c) Stomium (d) Protostomium
87. A mismatch is [Chd. CET 2000]  
(a) Odd toe-Horse (b) *Pheretima*-parapodia  
(c) *Hydra*-Cnidaria (d) Cartilaginous Fish-Shark
88. The nerve chord in earthworm originates from [NCERT; AMU (Med.) 2012]  
(a) Supra-pharyngeal ganglia and has a fused pair of ganglia in each segment from the 3<sup>rd</sup> to the last  
(b) Supra-pharyngeal ganglia and has a fused pair of ganglia in each segment from the 4<sup>th</sup> to the last  
(c) Sub-pharyngeal ganglia and has fused pair of ganglia in each segment from the 5<sup>th</sup> to the last  
(d) Sub-pharyngeal ganglia and has a fused pair of ganglia in each segment from the 6<sup>th</sup> to the last
89. *Pheretima* and its close relatives derive nourishment from [NCERT; CBSE PM T (Pre.) 2012]  
(a) Sugarcane roots  
(b) Decaying fallen leaves and soil organic matter  
(c) Soil insects  
(d) Small pieces of fresh fallen leaves of maize, etc
90. In Earthworm, neurons are [CPMT 2000; BHU 2006]  
(a) Sensory (b) Motor  
(c) Both (a) and (b) (d) Mixed
91. In *Pheretima*, septa are absent [CPMT 2000]  
(a) 5/6, 10/11 (b) 5/6, 7/8  
(c) 6/7, 7/8 (d) First four segments
92. Enteronephric nephridia of earthworm are concerned with [CBSE PM T 2000]  
(a) Excretion (b) Respiration  
(c) Digestion (d) Osmoregulation
93. Blood vessel in *Pheretima* having valves is [AIIMS 2000]  
(a) Dorsal (b) Ventral  
(c) Lateral (d) Integumentary
94. Oxygen carrying blood pigment of Earthworm is [Kerala PM T 2000]  
Or  
Which of the following is absent in the coelomic fluid of earthworm [AFMC 2012]  
(a) Haemocyanin (b) Haemoglobin  
(c) Haemoerythrin (d) Chlorocruorin  
(e) Pinnaglobin
95. Nephridia of *Pheretima* are [RPM T 2000]  
(a) Protonephridia (b) Solenocytes  
(c) Micrometanephridia (d) Meganephridia
96. In Earthworm the dorsal wall of the intestine from the 26<sup>th</sup> segment to 95<sup>th</sup> segment forms a median internal fold called [Kerala CET 2005, 07]  
(a) Trochophore (b) Typhlosole  
(c) Clitellum (d) Trachea  
(e) Nephridium
97. Which is not correct for Earthworm [CPMT 2001]  
(a) It walks with a speed of 25 cm/min  
(b) It can remain without oxygen for 6-30 hrs  
(c) Life span is 3.5 – 10 years  
(d) Setae easily dissolve in KOH
98. In *Pheretima* coelomic fluid contains [BHU 2001]  
(a) Dissolved haemoglobin (b) Dissolved RBC  
(c) Broken WBC (d) Watery plasma
99. Locomotory organ of annelida is [Odisha JEE 2011]  
(a) Sucker (b) Parapodia  
(c) Setae (d) All of these
100. External segmentation is absent but internal segmentation is present in [APME E 2001]  
(a) Polychaeta (b) Oligochaeta  
(c) Archiannelida (d) Hirudinea
101. See the following figure and identify A to F [NCERT]



Dorsal view of earthworm

	A	B	C	D	E	F
(a)	Prostomium	Peristomium	Endo-steum	Cloaca	Metamer es	Ring of setae
(b)	Prostomium	Peristomium	Endo-steum	Anus	Metamer es	Ring of setae
(c)	Prostomium	Peristomium	Clitellu m	Anus	Metamer es	Ring of setae
(d)	Peristomium	Prostomium	Clitellu m	Anus	Metamer es	Ring of setae

102. Phaosome in Earthworm is [APME E 2002]  
(a) Lens (b) Pigment  
(c) Nephridium (d) Hormone
103. In earthworms setae are present in all segments except [NCERT; CPMT 1993; RPM T 1994; Kerala PM T 2011]  
(a) First and the last segments  
(b) First and the clitellum  
(c) First segment  
(d) Clitellum and last segments  
(e) First clitellum and last segments

104. Which one will excrete silicates consumed by Earthworm alongwith food [APMEE 2002]  
(a) Intestinal cells (b) Basal cells  
(c) Chloragogen cells (d) Flame cells
105. Pharyngeal nephridia of Earthworm *Pheretima* occur in segments [NCERT; CMC 2002]  
(a) 3, 4 and 5 (b) 4, 5 and 6  
(c) 5, 6 and 7 (d) 6, 7 and 8
106. Bilateral symmetry, blastopore mouth and true coelom occur in [CMC 2002]  
(a) Echinodermata (b) Chordata  
(c) Annelida (d) Platyhelminthes
107. Which one is correct [Odisha JEE 2002]  
(a) Flatworms are eucoelomates  
(b) Fishes are radially symmetrical  
(c) Birds are poikilothermic  
(d) Earthworm is metamerically segmented
108. Pick up the mismatched [Odisha JEE 2002]  
(a) Annelida – *Hydra*  
(b) Nematelminthes – *Ascaris*  
(c) Arthropoda – *Cockroach*  
(d) Echinodermata – Starfish
109. Locomotion occurs in Earthworm with the help of [RPMT 2002]  
(a) Setae  
(b) Setae and circular muscles  
(c) Parapodia  
(d) Setae, circular muscles and longitudinal muscles
110. Which of the following nephridia does not found in earthworm [AFMC 2004]  
(a) Septal nephridia (b) Macro nephridia  
(c) Integumentary nephridia (d) Pharyngeal nephridia
111. In which phylum the body is segmented [MP PMT 2010]  
(a) Porifera (b) Coelenterata  
(c) Annelida (d) Mollusca
112. Which one of the following species of earthworm is not recommended for vermicomposting [KCET 2010]  
(a) *Eudrilus eugeniae* (b) *Eisenia fetida*  
(c) *Perionyx excavatus* (d) *Pheretima posthuma*
113. Which of the following is incorrect for *Pheretima* [CPMT 2010]  
(a) Genital papillae are present on 17<sup>th</sup> and 19<sup>th</sup> segment  
(b) Male genital pores are present on 18<sup>th</sup> segment  
(c) Clitellum is present on segments 24, 25 and 26  
(d) Segments of earthworm are called somites
114. The breakdown of detritus into smaller particles by earthworm is a process called [CBSE PMT (Mains) 2011; NEET 2013; KCET 2015]  
(a) Mineralisation (b) Catabolism  
(c) Humification (d) Fragmentation
115. Which one of the following structures in *Pheretima* is correctly matched with its function [CBSE PMT (Mains) 2011]  
(a) Setae – defence against predators  
(b) Typhlosole – storage of extra nutrients  
(c) Clitellum – secretes cocoon  
(d) Gizzard – absorbs digested food
2. The presence of compound eyes is characteristics of the phylum [VITEEE 2008; WB JEE 2008]  
(a) Nematoda (b) Mollusca  
(c) Echinodermata (d) Arthropoda
3. Which of the following is not an arachnid [AFMC 2008]  
(a) Spider (b) Itchmite  
(c) Louse (d) Tick
4. The process of conversion of a small cockroach into an adult cockroach is called as [RPMT 1999]  
(a) Moulting (b) Metamorphosis  
(c) Ecdysis (d) Transformation
5. 'Hexapoda' is another name of [RPMT 1999]  
(a) Crustacea (b) Arachnida  
(c) Insecta (d) Archiannelid
6. Glow worm is  
(a) Annelid (b) Helminthes  
(c) Insect (d) Mollusca
7. Which thing is common in leech, mosquito bed bug and rat [AIIMS 1993]  
(a) All have anticoagulant  
(b) All have nucleus  
(c) All have no cellular membrane  
(d) All have sexual phase
8. Cockroach belongs to class [RPMT 1999]  
(a) Hexapoda (b) Apoda  
(c) Myriapoda (d) Cephalopoda
9. The image formed in the eyes of cockroach is [RPMT 1999]  
(a) Apposition (b) Superposition  
(c) Both (a) and (b) (d) None of these
10. What is common among silver fish, scorpion, crab and honey bee [CBSE PMT 1998; AIIMS 2007]  
(a) Compound eyes (b) Poison glands  
(c) Jointed legs (d) Metamorphosis
11. Which one of the following groups of three animals each is correctly matched with their one characteristic morphological feature [CBSE PMT 2008]

Animals	Morphological feature
(a) Scorpion, Spider, Cockroach	Ventral solid central nervous system
(b) Cockroach, Locust, Taenia	Metameric segmentation
(c) Liver fluke, Sea anemone, Sea cucumber	Bilateral symmetry
(d) Centipede, Prawn, Sea urchin	Jointed appendages

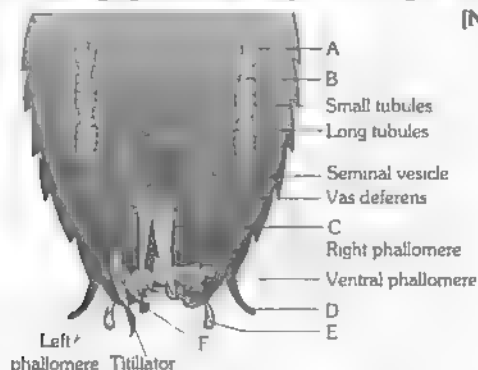
12. A moth is closely related to  
(a) Butterfly (b) Cricket  
(c) Beetle (d) Wasp
13. Which one of the following is the true description about an animal concerned [NCERT; Manipal 2005; CBSE PMT 2008]  
(a) Rat – Left kidney is slightly higher in position than the right one  
(b) Cockroach – 10 pairs of spiracles (2 pairs on thorax and 8 pairs on abdomen)  
(c) Earthworm – The alimentary canal consists of a sequence of pharynx, oesophagus, stomach gizzard and intestine  
(d) Frog – Body divisible into three regions – head, neck and trunk

### Phylum-Arthropoda

1. Which of the following features is not present in *periplaneta Americana* [NEET (Phase-I) 2016]  
(a) Schizocoelom as body cavity  
(b) Indeterminate and radial cleavage during embryonic development  
(c) Exoskeleton composed of N-acetylglucosamine  
(d) Metamerically segmented body

14. The biggest phylum in regard to the number of species is  
[NCERT; CPMT 1994]
- Or
- Which one of the following have the highest number of species in nature  
[CBSE PMT (Pre.) 2011]
- (a) Arthropoda (b) Platyhelminthes  
(c) Chordata (d) Protozoa
15. The arthropods do not possess [IEMCET 1998]  
(a) True coelom (b) Exoskeleton  
(c) Haemocoel (d) Malpighian body
16. The number of abdominal segments in male and female cockroach is  
[NCERT; Kerala PMT 2008]  
(a) 10, 10 (b) 9, 10  
(c) 10, 11 (d) 8, 10  
(e) 9, 9
17. Which of the following is absent in the mouth part of housefly  
[APMEE 1995; CPMT 1999; MH CET 2003]  
(a) Labrum (b) Epipharynx  
(c) Mandibles (d) Maxillary palps
18. Which of the following animals is unisexual  
[Kerala PMT 2008]  
(a) Tapeworm (b) Leech  
(c) Sponge (d) Earthworm  
(e) Cockroach
19. Which of the following is not a characteristic features of arthropods  
[J & K CET 2012]  
(a) Jointed appendages (b) Unsegmented body  
(c) Moulting (d) Articulated exoskeleton
20. Note the following :  
(A) Fenestra (B) Pedicel (C) Lacinia  
(D) Flagellum (E) Geleae (F) Mentum  
(G) Palpifer (H) Cando (I) Glossa  
Which of the above found in the first pair of maxillae in the case of Cockroach [IEMCET 2009; AMU (Med.) 2010, 12]  
(a) C, E G and H (b) A, C, E and I  
(c) A, F, G and I (d) B, E, G and I
21. In cockroach, which of the following is the principal motor centre  
[IEMCET 2009]  
(a) Supraoesophageal ganglia  
(b) Suboesophageal ganglia  
(c) Metathoracic ganglia  
(d) Abdominal ganglia
22. The terga, sterna and pleura of cockroach body are joined by  
[AIPMT (Cancelled) 2015]  
(a) Muscular tissue (b) Arthrodiol membrane  
(c) Cartilage (d) Cementing glue
23. Spiders and scorpions are included in class  
[CBSE PMT 1993; CPMT 2010]  
(a) Arachnida (b) Echarida  
(c) Actinozoa (d) Anthozoa
24. Book-lungs are respiratory organs which are found in  
[AFMC 2009]  
(a) Insects (b) Crustaceans  
(c) Arachnids (d) Onychophores
25. Stink gland is found in [CPMT 2009]  
(a) 4<sup>th</sup> and 5<sup>th</sup> terga of cockroach  
(b) 5<sup>th</sup> and 6<sup>th</sup> terga of cockroach  
(c) 5<sup>th</sup> and 6<sup>th</sup> sterna of cockroach  
(d) 4<sup>th</sup> and 5<sup>th</sup> sterna of cockroach
26. Maximum number of economically important species are in the class  
[MP PMT 2006]
- Or
- Which of the following classes has largest number of animals  
[MP PMT 1998]  
(a) Diplopoda (b) Chilopoda  
(c) Crustacea (d) Insecta
27. Which of the following is not an insect  
[RPMT 1995, 99; AFMC 1996; KCET 1997; RPMT 1999; BVP 2002]  
(a) Cockroach, beetle (b) Bed bug  
(c) Mosquito, wasp (d) Spider, Tick
28. Which of the following features is not present in the phylum – Arthropoda  
[NEET (Phase-I) 2016]  
(a) Chitinous exoskeleton  
(b) Metameric segmentation  
(c) Parapodia  
(d) Jointed appendages
29. What is the similarity between cockroach, anopheles and housefly  
[CPMT 1996]  
(a) Cuticle covering the body  
(b) Two pair wings  
(c) Three pair legs  
(d) Presence of cephalothorax
30. The common characters found in centipede, cockroach, and crab are  
[CBSE PMT 2006]  
(a) Green gland and tracheae  
(b) Book lungs and antennae  
(c) Compound eyes and anal cerci  
(d) Jointed legs and chitinous exoskeleton
31. Crayfish is a [MP PMT 1998]  
(a) Crustacean animal (b) Edible fish  
(c) Poisonous fish (d) None of the above
32. Which one of the following has an open circulatory system  
[CBSE PMT 2006]  
(a) Hirudinaria (b) Octopus  
(c) Pheretima (d) Periplaneta
33. In which of the following sets all are vectors  
[NCERT; CPMT 1998]  
(a) *Physalia*, *Musca domestica*, *Anopheles*  
(b) *Amoeba*, *Physalia*, *Musca*  
(c) *Anopheles*, *Musca*, *Culex*  
(d) All of the above
34. *Phlebotomus argentipus* is a vector for [IEMCET 1998]  
(a) *Trypanosoma evansi* (b) *Trypanosoma gambiense*  
(c) *Leishmania donovani* (d) *Trypanosoma cruzi*

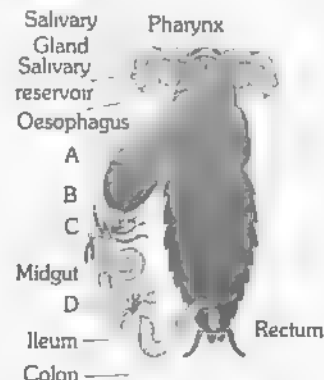
35. See the following figure and identify A to F in given diagram [NCERT]



	A	B	C	D	E	F
(a)	Testis	Phallic gland	Ejaculatory duct	Caudal style	Anal cercus	Pseudo penis
(b)	Testis	Phallic gland	Ejaculatory duct	Anal cercus	Caudal style	Pseudo penis
(c)	Testis	Collateral gland	Ejaculatory duct	Terga	Caudal style	Pseudo penis
(d)	Testis	Collateral gland	Ejaculatory duct	Anal cercus	Caudal style	Pseudo penis

36. Respiration pigment of blood in cockroach is [RPMT 2006]  
 (a) Haemozoin (b) Haemocyanin  
 (c) Haemoglobin (d) Absent
37. Which is a matching set in taxonomy [CMC Vellore 1993]  
 (a) Leech, locust, sea urchin, lobster  
 (b) Star fish, jelly fish, cuttle fish, octopus  
 (c) Milliped, crab, centipede, cockroach  
 (d) Nereis, planaria, round worm, earthworm
38. Book lungs are the respiratory organs in [NCERT; RPMT 2006]  
 (a) Protozoans (b) Cnidarians  
 (c) Arthropodes (d) Amphibians
39. The taste receptors of cockroach are [DPMT 2006]  
 (a) Compound eyes  
 (b) Campaniform sensillae  
 (c) Palps of maxillary and labium  
 (d) Tactile hairs
40. Bilateral symmetry, metameric segmentation coelom and open circulatory system are the characters of [MP PMT 2009]  
 (a) Annelida (b) Arthropoda  
 (c) Mollusca (d) Echinodermata
41. *Pasteurella/Yersinia pestis* (causal agent of Bubonic Plague) is transmitted by [APMEE 1995]  
 (a) Bed bug/*Cimex* (b) Rat flea/*Xenopsylla*  
 (c) Louse/*Pediculus* (d) Mosquito/*Aedes*
42. Among the following, colonial insects are [BHU 2006]  
 (a) Locusts (b) Mosquitoes  
 (c) White ants (d) Bed bug
43. Complete metamorphosis is observed in  
 (a) Silver Fish (b) Gypsy Moth  
 (c) Bed Bug (d) Grasshopper
44. Basic unit in the eye of Cockroach/insect is [NCERT; APMEE 1995; Pb. PMT 1999; HPMT 2002]  
 (a) Retina (b) Rhabdome  
 (c) Corneal facet (d) Ommatidium
45. Malpighian tubules are [NCERT; BHU 2006]  
 (a) Excretory organs of insects  
 (b) Excretory organs of frog  
 (c) Respiratory organs of insects  
 (d) Endocrine glands of insects
46. Structure common between Earthworm and Cockroach is [NCERT; CPMT 1994; AFMC 1994; RPMT 2005]  
 Or  
 Which one of the following features is common to earthworm, butterfly, spider and prawn [WB JEE 2016]  
 Or  
 Which one feature is common to leech Cockroach and scorpion [AIIMS 2004, 08]  
 (a) Cocoon (b) Ommatidia  
 (c) Dorsal nerve cord (d) Ventral nerve cord
47. Tumbler is pupa of  
 (a) Housefly (b) Mosquito  
 (c) Butterfly (d) Beetle
48. What is common between earthworm and *Periplaneta* [AIIMS 2012]  
 (a) Both have red coloured blood  
 (b) Both possess anal styles  
 (c) Both have Malpighian tubules  
 (d) Both have segmented body
49. In cockroach, larval and nymphal characters are maintained by [BHU 2006]  
 (a) Ecdysone (b) Salivary glands  
 (c) Parotid gland (d) Juvenile hormone
50. The correct sequence of arrangements of segments in the leg of cockroach is [Kerala PMT 2006]  
 (a) Tibia, Trochanter, Femur, Tarsus and Coxa  
 (b) Trochanter, Coxa, Tibia, Femur and Tarsus  
 (c) Coxa, Femur, Trochanter, Tibia and Tarsus  
 (d) Coxa, Trochanter, Femur, Tibia and Tarsus  
 (e) Trochanter, Coxa, Femur, Tarsus and Tibia
51. Mouth parts of a butterfly are of type  
 (a) Sponging (b) Siphoning  
 (c) Piercing and sucking (d) Chewing and sucking
52. Conglobate gland occurs in [BCECE 2005; BHU 2008]  
 (a) Female cockroach (b) Male cockroach  
 (c) Anopheles mosquito (d) Culex mosquito
53. Similarity between *Anopheles* and *Culex* is [AFMC 2010]  
 (a) Eggs are laid in floating raft  
 (b) Respiratory siphon is present  
 (c) Eggs have lateral air floats  
 (d) Males of both suck juices of flowers and fruits
54. In Housefly the larva lives in [BHU 1995]  
 (a) Water (b) Muddy soil  
 (c) Dung (d) Vegetation

55. In *Pheretima*, septa are absent between which segments [BHU 2006]  
 (a) 3/4 and 9/10 (b) 4/5 and 8/9  
 (c) 5/6 and 7/8 (d) 7/8 and 6/7
56. The ingrowth of exoskeleton in the head of cockroach is called [AFMC 2012]  
 (a) Notum (b) Apodemes  
 (c) Pleura (d) Tentorium
57. An insect without pupa stage is  
 (a) Mosquito (b) Silk Moth  
 (c) Bed Bug (d) Butterfly
58. Young Housefly/Mosquito is known as  
 (a) Maggot (b) Caterpillar  
 (c) Nymph (d) Imago
59. Which set includes pathogenic Arthropods [AFMC 2006]  
 (a) Tse-tse fly, mosquito, flea-plague  
 (b) Crab, *Culex*, spider  
 (c) *Anopheles*, *Culex*, cray fish  
 (d) Silver fish, house fly, sandfly
60. Which of the following causes parasitic castration of crab [BHU 2012]  
 (a) *Sacculina* (b) *Adamsia*  
 (c) *Spongilla* (d) None of these
61. Ecdysone is produced by  
 (a) Prothoracic gland (b) Corpora allata  
 (c) Corpora cardiaca (d) Abdominal gland
62. Cockroach is  
 (a) Carnivorous (b) Herbivorous  
 (c) Omnivorous (d) Sanguivorous
63. Johnston's organ found in [Bihar MDAT 2002]  
 (a) Antenna of Mosquito (b) Head of Cockroach  
 (c) Abdomen of Housefly (d) Abdomen of Spider
64. Which disease is spread by Housefly [CPMT 1993]  
 (a) Dengue fever (b) Encephalitis  
 (c) Filariasis (d) Gangrene
65. Halteres in Mosquitoes and Housefly develop from  
 (a) Prothorax (b) Metathorax  
 (c) Mesothorax (d) Head
66. Mouth parts of Cockroach are of [NCERT; BHU 1999; RPMT 2000; CPMT 2001]  
 (a) Piercing and sucking (b) Sucking and siphoning  
 (c) Cutting and biting type (d) Sucking and rasping
67. In insect, oxygen is carried to different tissues by  
 Or  
 In Insects, respiratory gas exchange occurs through [HPMT 2002]  
 (a) Diffusion through surface  
 (b) Tracheal tubes  
 (c) Respiratory pigment through blood  
 (d) Gills
68. Wings are vestigial in Cockroach [CPMT 1997]  
 (a) Female *Blatta orientalis*  
 (b) Male *Blatta orientalis*  
 (c) Male *Periplaneta americana*  
 (d) Female *Periplaneta americana*
69. Anal cerci occur in  
 (a) Both male and female cockroaches  
 (b) Male Cockroach  
 (c) Female Cockroach  
 (d) Female *Ascaris*
70. In the life cycle of mosquito, comma-shaped stage is [DPMT 2004]  
 (a) Larval stage (b) Pupal stage  
 (c) Imago stage (d) None of these
71. The order of metamorphosis in Housefly is [AIIMS 1999; JIPMER 2000]  
 (a) Egg, nymph, pupa and adult  
 (b) Egg, larva, nymph and adult  
 (c) Egg, larva, pupa and adult  
 (d) Egg, pupa, larva and adult
72. An aquatic living fossil, with ancient origin and many primitive characters which respire through book gills is [NCERT; AMU (Med.) 2012]  
 (a) *Limulus* (b) *Cancer*  
 (c) *Lucifer* (d) *Daphnia*
73. Hormone produced by corpora allata in insects is [APMEE 1996; AIIMS 1997; Manipal 2001; AMU (Med.) 2009]  
 (a) Growth hormone (b) Moulting hormone  
 (c) Inhibiting hormone (d) Juvenile hormone
74. Male and female Cockroaches can be distinguished externally through [CBSE PMT 1991; Pb. PMT 1994, 97; RPMT 1995, 98, 2001; CPMT 1996, 98; Kerala PMT 2007; Odisha JEE 2012; NEET (Karnataka) 2013]  
 (a) Anal styles in male  
 (b) Anal cerci in female  
 (c) Anal style and antennae in females  
 (d) Both (a) and (c)
75. *Periplaneta* shows [RPMT 1995; AFMC 2002]  
 (a) Complete metamorphosis  
 (b) Incomplete metamorphosis  
 (c) No metamorphosis  
 (d) Gradual metamorphosis
76. Housefly feeds on sugar by  
 (a) Crushing its crystals and then sucking the power  
 (b) Crushing and eating  
 (c) Sucking  
 (d) Dissolving in saliva and sucking
77. Metamorphosis of insects is regulated through hormone [CBSE PMT 1991; BHU 1998, 2001; RPMT 1998; Pb. PMT 1999]  
 (a) Pheromone (b) Thyroxine  
 (c) Ecdysone (d) All the above
78. See the following figure and identify structure A, B, C and D [NCERT]

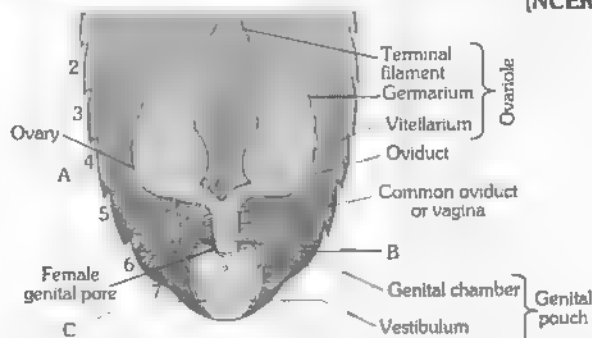


	A	B	C	D
(a)	Gizzard	Crop	Malpighian tubules	Hepatic caecae
(b)	Crop	Gizzard	Malpighian tubules	Hepatic caecae
(c)	Crop	Gizzard	Hepatic caecae	Malpighian tubules
(d)	Gizzard	Crop	Hepatic caecae	Malpighian tubules

79. In Cockroach, the number of ganglia are [AFMC 1993]  
 (a) Two pairs thoracic and four pairs abdominal  
 (b) Three pairs thoracic and six pairs abdominal  
 (c) Three pairs thoracic and five pairs abdominal  
 (d) Two pairs thoracic and six pairs abdominal
80. Mouth part present in female *Anopheles* but absent in male ■  
 (a) Maxillae (b) Antennae  
 (c) Proboscis (d) Mandibles
81. An insect regarded as greatest mechanical carrier of disease is [CBSE PMT 1991]  
 (a) *Pediculus* (b) *Cimex*  
 (c) *Musca* (d) *Xenopsylla*
82. Which insect is called 'Horn Beetle' [CPMT 2005]  
 (a) *Tribolium* (b) *Concya*  
 (c) *Trogoderma* (d) None of these
83. Which of the following is an  $r$  – strategist [DUMET 2010]  
 (a) Human (b) Insect  
 (c) Rhinoceros (d) Whale
84. The major excretory product of arthropods is [NCERT; Bihar MDAT 1994]  
 (a) Ammonia (b) Urea  
 (c) Uric acid (d) Trimethylamine oxide
85. Common feature between housefly and honey bee is [Pb. PMT 2004]  
 (a) Head (b) Mouthparts  
 (c) Abdomen (d) Three pairs of jointed legs
86. Adult *Culex* and *Anopheles* can be distinguished with the help of [CBSE PMT 1992, 93; KCET 1998]  
 (a) Mouth parts/colour (b) Sitting posture  
 (c) Antennae/wings (d) Feeding habits
87. A larval stage occurs in the life history of all members of the group [CBSE PMT 1993]  
 (a) Frog, Lizard and Cockroach  
 (b) *Ascaris*, Housefly and Frog  
 (c) Housefly, Earthworm and Mosquito  
 (d) Butterfly, frog and Mosquito
88. Difference between male and female *Anopheles* occurs in [CBSE PMT 1993]  
 (a) Proboscis (b) Wings  
 (c) Antennae (d) Size
89. Tracheae of Cockroach and Mammal are similar in having [CBSE PMT 1993]  
 (a) Paired nature (b) Noncollapsible walls  
 (c) Ciliated inner lining (d) Origin from head
90. Pupa occurs in the life cycle of [CPMT 1994]  
 (a) Cockroach (b) Housefly  
 (c) Honey Bee (d) Both (b) and (c)
91. Which part of Cockroach has both exoskeleton and endoskeleton [RPMT 1995]  
 (a) Head (b) Thorax  
 (c) Abdomen (d) All the above
92. In Cockroach, wings are absent from [NCERT; RPMT 1995]  
 (a) Prothorax (b) Mesothorax  
 (c) Metathorax (d) None of the above
93. The first animals to fly were [RPMT 1995]  
 (a) Mammals (b) Lizards  
 (c) Birds (d) Insects
94. Which is nonpoisonous [MP PMT 1995]  
 (a) Scorpion (b) Centipede  
 (c) Crab (d) Spider
95. Which one is a tracheate group [MP PMT 1995]  
 (a) King Crab – scorpion – Housefly  
 (b) Crab – Centipede – Cockroach  
 (c) Spider – Peripatus – Mosquito  
 (d) Bed Bug – Sandfly – Silkworm
96. In Cockroach, metamorphosis requires [RPMT 1996]  
 (a) Three weeks (b) 40-70 days  
 (c) 10-30 days (d) 5-13 days
97. Male cockroach can be distinguished from female cockroach through [RPMT 1996]  
 (a) Longer antennae (b) Longer abdomen  
 (c) Wingless body (d) All the above
98. Cockroach blood does not contain respiratory pigment. It means [RPMT 1996; AFMC 1998]  
 (a) It does not respire  
 (b) Cockroach respire anaerobically  
 (c) Oxygen passes to all the tissues through diffusion  
 (d) Oxygen reaches tissue through tracheoles
99. Which is common amongst Fly, Mosquito and Cockroach [CPMT 1996]  
 (a) Open excretory system (b) Two pairs of wings  
 (c) All belong to class Insecta (d) 13-chambered heart
100. *Periplaneta* differs from *Blatta* in [CPMT 1996]  
 (a) Reduced wings in *Blatta* and developed wings in *Periplaneta*  
 (b) Reverse of (a)  
 (c) Anal styles  
 (d) Anal cerci
101. Which is characteristic of Cockroach [NCERT; BHU 1996, 98, 2001; CPMT 1996, 2009; HP PMT 2005]  
 (a) 13-chambered heart (b) Reduced wings  
 (c) Cocoon formation (d) Segmented body
102. Arrhenotoky is parthenogenetic development found in [AIIMS 1996]  
 (a) All insects  
 (b) Mosquitoes  
 (c) Butterflies  
 (d) Honey bees, Wasps and Ants
103. Sandfly is [Bihar MDAT 1996]  
 (a) *Ancylostoma* (b) *Musca*  
 (c) *Phlebotomus* (d) *Drosophila*
104. In Cockroach the longest podomere is [Bihar MDAT 1996]  
 (a) Coxa (b) Trochanter of Femur  
 (c) Tibia (d) Tarsus
105. Tick the correct matching [DPMT 1996]  
 (a) Arachnida — Ticks, Mites  
 (b) Prototheria — Scaly Anteater  
 (c) Prokaryotes — Green Algae  
 (d) Annelida — *Ascaris*, *Taenia*

106. Which one possess larval stages [DPMT 1996]  
 (a) Cockroach and Housefly  
 (b) Housefly and Butterfly  
 (c) Cockroach and Honey Bee  
 (d) Grasshopper and Dragonfly
107. In Butterfly, long coiled siphoning tubes is formed from [APMEE 1996]  
 (a) Labrum (b) Maxilla  
 (c) Labium (d) Mandibles
108. If juvenile hormone is absent when silkworm moults, it will [CBSE PMT 1997]  
 (a) Moults into another larval stage  
 (b) Moults into pupa  
 (c) Moults into adult  
 (d) Die
109. Which is absent in arthropoda [JIPMER 1997]  
 (a) Compound eye  
 (b) Chitinous exoskeleton  
 (c) Closed blood vascular system  
 (d) Malpighian tubules
110. Swarming is found in [MP PMT 1998]  
 (a) Houseflies (b) Mosquitoes  
 (c) Locusts (d) Pyrrilla
111. Complete metamorphosis present in [CPMT 2002; RPMT 2006]  
 (a) House fly and mosquito  
 (b) House fly and cockroach  
 (c) Mosquito and cockroach  
 (d) None of the above
112. Pseudotrachea of Housefly is formed by [CPMT 1998]  
 (a) Labella (b) Rostrum  
 (c) Haustellum (d) Basiproboscis
113. Spiracles of Cockroach which are larger and always kept open are [RPMT 1998]  
 (a) First and second pairs (b) First and third pairs  
 (c) First and tenth pairs (d) Second and third pairs
114. Corpora allata are removed from a nymph. It will [RPMT 1998]  
 (a) Remain nymph for life  
 (b) Become adult  
 (c) Change to next nymph immediately but will remain in that state  
 (d) Die after some time
115. *Aedes* is vector of [RPMT 1998]  
 (a) Plague (b) Malaria  
 (c) Filaria (d) Encephalitis and Dengue
116. Antennae of Cockroach have [RPMT 1998]  
 (a) Gustatory receptors  
 (b) Auditory receptors  
 (c) Tactile receptors  
 (d) Tactile and olfactory receptors
117. Which is wrong for an insect [RPMT 1998]  
 (a) Cephalization and unjointed appendages  
 (b) Chitinous exoskeleton and wings  
 (c) Cephalisation and complete metamorphosis  
 (d) Well developed sensory organs and haemocoel
118. Millipede (*Julus*) and Centipede (*Scolopendra*) are both included under [RPMT 1998]  
 (a) Arachnida (b) Myriapoda  
 (c) Scaphopoda (d) Pelecypoda
119. Spider prepares the web with the help of [JIPMER 1999]  
 (a) Legs (b) Mouth  
 (c) Spinnerets (d) Salivary glands
120. Open circulatory system is not of physiological hindrance in Cockroach because [AIIMS 1999]  
 (a) Heart is simple but chambered  
 (b) Blood is colourless  
 (c) Circulatory and respiratory systems are not connected  
 (d) Excretion occurs through malpighian tubules
121. In cockroaches, digestive juice is secreted by the [NCERT; Kerala PMT 2012]  
 (a) Gizzard (b) Malpighian tubules  
 (c) Crop (d) Oesophagus  
 (e) Hepatic caeca
122. Number of fertilized eggs in ootheca of Cockroach is [NCERT; BHU 1999; Kerala PMT 2000; Manipal 2001]  
 (a) 16 pairs in two rows (b) 16 in two rows  
 (c) 10 in one rows (d) 8 in two rows
123. In Cockroach, ootheca is produced by secretion of [APMEE 1999]  
 (a) Conglobate gland (b) Phallic gland  
 (c) Collateral gland (d) Mushroom gland
124. Hard exoskeleton cephalothorax and gills for respiration are characteristics of [AFMC 2000]  
 (a) Insecta (b) Myriapoda  
 (c) Polychaeta (d) Crustacea
125. *Palaeomon* (Prawn) is a [J & K CMEE 2000]  
 (a) Insect (b) Crustacean  
 (c) Soft shelled mollusc (d) Fish
126. Arachnida contains [J & K CMEE 2000]  
 (a) Wasps (b) Insects  
 (c) Spiders (d) Beetles
127. *Ascaris* and Cockroach resemble each other in [CBSE PMT 2000]  
 (a) Pseudocoel (b) Sexual dimorphism  
 (c) Nephridia (d) Dorsal tubular nerve cord
128. Which among the following is a social insect [CPMT 2000]  
 (a) White Ants (b) Locusts  
 (c) Bed Bugs (d) Mosquitoes
129. *Periplaneta* belongs to phylum [NCERT; Odisha JEE 2012]  
 (a) Annelida (b) Mollusca  
 (c) Echinodermata (d) Arthropoda
130. Select the correct statement from the ones given below with respect to *Periplaneta americana* [CBSE PMT (Pre.) 2012]  
 (a) Nervous system located dorsally, consists of segmentally arranged ganglia joined by a pair of longitudinal connectives  
 (b) Males bear a pair of short thread like anal styles  
 (c) There are 16 very long Malpighian tubules present at the junctions of midgut and hindgut  
 (d) Grinding of food is carried out only by the mouth parts

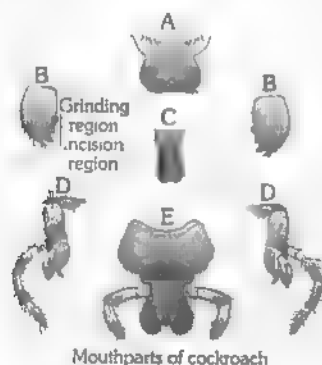
131. A female *Anopheles* mosquito can be recognized by [WB JEE 2011]  
 (a) Proboscis and palpi are long and more or less of equal length  
 (b) Proboscis long and palpi short  
 (c) Proboscis short and palpi long  
 (d) Both proboscis and palpi are short
132. The open circulatory system is found in [Odisha JEE 2011]  
 (a) Earthworm (b) Cockroach  
 (c) Snail (d) Both (b) and (c)
133. Holometaboly is found in [Kerala PMT 2000]  
 (a) Lady Bird Beetle (b) Bed Bug  
 (c) Cockroach (d) Grass Hopper  
 (e) Silver Fish
134. Number of malpighian tubules present in Cockroach is [RPMT 2000]  
 (a) 50-60 (b) 80-90  
 (c) 100-150 (d) 200-250
135. Arthropoda is differentiated from annelids by [BHU 2000]  
 (a) Segmented body (b) Absence of nephridia  
 (c) Eyes (d) None of the above
136. An arthropod belonging to onychophora which possesses nephridia is [BHU 2001]  
 (a) *Limulus* (b) *Peripatus*  
 (c) *Daphnia* (d) *Lepisma*
137. Paurometaboly is [KCET 2001]  
 (a) Complete metamorphosis  
 (b) Gradual metamorphosis  
 (c) Incomplete metamorphosis  
 (d) Complete metabolism
138. About how many times does the nymph of the *Periplaneta americana* undergo moulting before becoming an adult [NCERT; Kerala PMT 2011]  
 (a) 4 (b) 2  
 (c) 17 (d) 3  
 (e) 13
139. Number of moults undergone by caterpillar of *Bombyx mori* is [APMEE 2001]  
 (a) 2 (b) 4  
 (c) 6 (d) 8
140. Tripedal locomotion occurs in [APMEE 2001]  
 (a) Kangaroo (b) Cockroach  
 (c) Snail (d) Earthworm
141. Which one of the following sets of animals shows a close taxonomic relationship [MP PMT 2001]  
 (a) Jelly fish, Cuttle fish, Cat fish  
 (b) Honey bee, Crayfish, Spider  
 (c) Alligator, Nautilus, Turtle  
 (d) Kangaroo, Octopus, Salamander
142. Class crustacea have which of the following feature [AIIMS 2001]  
 (a) Cephalothorax, biramous appendages and gills  
 (b) Cephalothorax, book lungs and chitinous exoskeleton  
 (c) Head and thorax, book lungs and chitinous exoskeleton  
 (d) Head and thorax, biramous appendages and book lungs
143. To which of the following class *Limulus* belongs [CPMT 2000; BVP 2001]  
 (a) Chilopoda (b) Arachnida  
 (c) Crustacea (d) Merostomata
144. Which of the following belongs to Phylum *Arthropoda/insecta* [RPMT 2001; DPMT 2004; NEET 2013]  
 (a) Star fish (b) Gold fish  
 (c) Silver fish (d) Cuttle fish
145. Caterpillar and maggot are [CPMT 2001]  
 (a) Larvae (b) Nymphs  
 (c) Adults (d) Pupa
146. The larva of Housefly lacks [BVP 2001]  
 (a) Eyes (b) Wings  
 (c) Spiracles (d) All of the above
147. Mouth parts of housefly are called as [BVP 2001; DPMT 2006]  
 (a) Biting & sucking type (b) Sponging & sucking type  
 (c) Biting & chewing type (d) None of these
148. Which one of the following is not a correct pair [RPMT 2001]  
 (a) Trochophore-Annelida (b) Bipinnaria-Echinodermata  
 (c) Tornaria-Arthropoda (d) Planula-Coelenterata
149. Crustacean fishery involves [MH CET 2002]  
 (a) Lobster and Prawn (b) Shells of Cuttle fish  
 (c) Mussels and Squids (d) Oysters and Crab
150. Wiggler is the larva of [JIPMER 2002]  
 (a) Cockroach (b) Mosquito  
 (c) Butterfly (d) Housefly
151. Superficial meroblastic cleavage occurs in [AFMC 2006]  
 (a) Reptiles (b) Birds  
 (c) Mammals (d) Insects
152. Which of the following respire by gills [J & K CET 2002, 05]  
 (a) Prawn (b) Frog  
 (c) Crocodile (d) Whale
153. Chitin is found in [J & K CET 2002]  
 (a) Mollusca (b) Arthropoda  
 (c) Echinodermata (d) Coelenterata
154. What distinguishes an insect from crustacean [J & K CET 2002, 05]  
 (a) Number of eyes  
 (b) Arrangement of nerve cords  
 (c) Number of appendages  
 (d) Presence of wings
155. Common feature in earthworm and cockroach is [NCERT; CPMT 2002]  
 (a) Cuticle (Exoskeleton)  
 (b) Solid and ventral nerve cord  
 (c) Nephridia  
 (d) Malpighian tubules
156. The given figure is of repr. System of femal cockroach. The correct labellings indicated by A, B and C are respectively [NCERT]



- (a) A – Spermatheca, B – Collateral glands, C – Tegmina  
 (b) A – Spermatheca, B – Seminal vesicle, C – Gonapophyses  
 (c) A – Phallic gland, B – Collateral glands, C – Gonapophyses  
 (d) A – Spermatheca, B – Collateral glands, C – Gonapophyses



157. Organ of mastication in cockroach is  
[NCERT; CPMT 2002; RPMT 2005; KCET 2012]  
(a) Labrum (b) Labium  
(c) Mandibles (d) Maxilla
158. Which of the following is an insect [CPMT 2002; RPMT 2005]  
(a) Moth (b) Mites  
(c) Prawn (d) Scorpion
159. In cockroaches during the digestion of food, the enzyme cellulase is synthesised by [HP PMT 2005]  
(a) Saliva  
(b) Lining cells of midgut  
(c) Bacteria in the midgut  
(d) Cellulase is never synthesised
160. In crustaceans, respiration takes place by [RPMT 2002]  
(a) Gills (b) Book lungs  
(c) Ctenidia (d) Trachea
161. Which of the following is correctly stated as happens in the common cockroach [CBSE PMT (Pre.) 2011]  
(a) The food is ground by mandibles and gizzard  
(b) Malpighian tubules are excretory organ projecting out from the colon  
(c) Oxygen is transported by haemoglobin blood  
(d) Nitrogenous excretory product is urea
162. Cray Fish belongs to [BHU 1998; AMU (Med.) 2002]  
(a) Pisces (b) Mollusca  
(c) Arthropoda (d) Anthozoa
163. Which one does not occur in Cockroach leg [DPMT 2002]  
(a) Tibia (b) Femur  
(c) Fibula (d) Coxa
164. Hind wings of mosquitoes are termed as [CPMT 1999; BHU 2002]  
(a) Coxa (b) Elytra  
(c) Halteres (d) Tentorium
165. The given figures are related with mouth parts of cockroach. Identify A to E



Mouthparts of cockroach

[NCERT]

	A	B	C	D	E
(a)	Labium	Hypopharynx	Labrum	Maxilla	Mandible
(b)	Labrum	Mandible	Hypopharynx	Maxilla	Labium
(c)	Mandible	Labium	Maxilla	Labrum	Hypopharynx
(d)	Maxilla	Hypopharynx	Labium	Mandible	Labrum

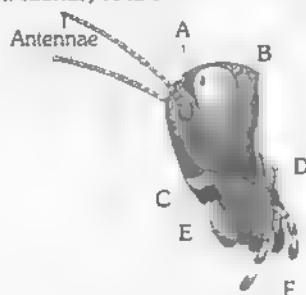
166. Match the columns and choose the exact combination

(A)	Ommatidia	(i)	Articulation with thorax
(B)	Trochanter	(ii)	For vision
(C)	Coxa	(iii)	Forming exoskeleton
(D)	Sclerites	(iv)	Fused with large and stout femur

[Manipal 2002]

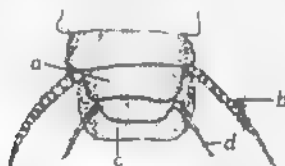
- (a) A—(iv), B—(iii), C—(i), D—(ii)  
(b) A—(i), B—(ii), C—(iii), D—(iv)  
(c) A—(ii), B—(iv), C—(i), D—(iii)  
(d) A—(iii), B—(i), C—(ii), D—(iv)
167. Ommatidia serve the purpose of photoreception in [CBSE PMT 2003; BHU 2012]  
(a) Sunflower (b) Cockroach  
(c) Frog (d) Humans
168. Mouth part of mosquito is [CPMT 2002; MH CET 2003; RPMT 2005]  
(a) Sucking and piercing type (b) Sponging type  
(c) Biting and chewing type (d) None of these
169. Vision in cockroach is [BVP 2003]  
(a) Monocular (b) Binocular  
(c) Ultrasonic (d) Mosaic
170. Which one of the following is a matching pair of an animal and a certain phenomenon it exhibits [CBSE PMT 2003]  
(a) Taenia – Polymorphism  
(b) Pheretima – Sexual dimorphism  
(c) Musca – Complete metamorphosis  
(d) Chamaeleon – Parthenogenesis
171. Haemocoel is found in [CPMT 1999; DPMT 2004; Odisha JEE 2011]  
(a) Hydra and Aurelia  
(b) Taenia and Ascaris  
(c) Balanoglossus and Herdmania  
(d) Cockroach and Pila
172. Universal character of insect is [MP PMT 2002; MH CET 2004; AFMC 2005; Odisha JEE 2008]  
(a) Two pair of wings (b) Compound eyes  
(c) Three pair of legs (d) Both (b) and (c)
173. Larvae of beetles are known as [Kerala PMT 2004]  
(a) Caterpillars (b) Grubs  
(c) Maggots (d) Naids
174. Scorpion belongs to a class to which one of the following also belong [DPMT 2003; BVP 2004]  
(a) Ticks (b) Crab  
(c) Barnacles (d) Cockroach
175. Blood of which of the following is colourless [HPMT 2005]  
(a) Earthworm (b) Leech  
(c) Cockroach (d) Frog
176. In Arthropoda, head and thorax are often fused to form cephalothorax, but one of the following classes is the body divide into head, thorax and abdomen [CBSE PMT 2004]  
(a) Crustacea  
(b) Arachnida and Crustacea  
(c) Insecta  
(d) Myriapoda

177. The given figure is associated with head region of cockroach. Identify A to F [NCERT]



	A	B	C	D	E	F
(a)	Ocellus	Compound eye	Maxilla	Mandible	Labium	Labrum
(b)	Ocellus	Compound eye	Mandible	Maxilla	Labium	Labrum
(c)	Ocellus	Compound eye	Mandible	Maxilla	Labrum	Labium
(d)	Compound eye	Ocellus	Maxilla	Mandible	Labrum	Labium

178. The diagram represents the reproductive organs of male cockroach. Choose the correct combination of labelling. [Kerala CET 2005]



- (a) a-8<sup>th</sup> sternum, b-anal cercus, c-10<sup>th</sup> tergum, d-anal style  
 (b) a-10<sup>th</sup> tergum, b-anal cercus, c-anal style, d-8<sup>th</sup> sternum  
 (c) a-anal style, b-anal cercus, c-10<sup>th</sup> tergum, d-8<sup>th</sup> sternum  
 (d) a-8<sup>th</sup> sternum, b-anal style, c-10<sup>th</sup> tergum, d-anal cercus  
 (e) a-anal cercus, b-8<sup>th</sup> sternum, c-10<sup>th</sup> tergum, d-anal style
179. What is common between an earthworm, a cockroach and a centipede [AIIEE Pharmacy 2004]  
 (a) Sexual dimorphism (b) Metamorphism  
 (c) Chitinous exoskeleton (d) Haemocoel
180. What is common between a moth, a frog and a mosquito [AIIEE Pharmacy 2004]  
 (a) The body is clearly differentiated into head, thorax and abdomen  
 (b) The life history is carried out in water  
 (c) The skin acts as the main respiratory organ  
 (d) Their larvae feed on a food different from that of the adult
181. The peculiar pungent smell of cockroach is produced by the secretions of [CPMT 2004]  
 (a) Pheromones (b) Flame cells  
 (c) Abdominal glands (d) Cervical glands
182. The cockroach of genus *Blatta* is also called [CPMT 2004]  
 (a) German cockroach (b) Australian cockroach  
 (c) Orient cockroach (d) American cockroach
183. The young one of cockroach is called [NCERT; KCET 2004]  
 (a) Caterpillar (b) Nymph  
 (c) Fingerling (d) Maggot
184. Which one of following feature is possessed by crustaceans and not by insects [CPMT 2005]  
 (a) Paired limbs (b) Two pairs of antenna  
 (c) Chitinous exoskeleton (d) Bilateral symmetry
185. The head of cockroach lacks [CPMT 2010]  
 (a) Cardo (b) Gena  
 (c) Trochanter (d) Frons
186. The adhesive pads (soft-pads) present in legs of cockroach are [AFMC 2005; KCET 2010]  
 (a) Galea (b) Lacinea  
 (c) Glossa (d) Plantulae
187. Which of the following are examples of arthropoda [Odisha JEE 2010; NEET 2013]  
 (a) Silver fish, star fish, prawn  
 (b) Clam worm, apple snail, honeybee  
 (c) Sea star, tongue worm, scorpion  
 (d) Cockroach, scorpion, prawn
188. Insects are [HPMT 2005; MP PMT 2006]  
 (a) Amminotelic (b) Ammonotelic  
 (c) Ureotelic (d) Uricotelic
189. Gizzard of cockroach is a part of [HPMT 2005]  
 (a) Respiratory system (b) Digestive system  
 (c) Immune system (d) Circulatory system
190. Which one of the following features is common in silverfish, scorpion, dragonfly and prawn [AIIMS 2005]  
 (a) Three pairs of legs and segmented body  
 (b) Chitinous cuticle and two pairs of antennae  
 (c) Jointed appendages and chitinous exoskeleton  
 (d) Cephalothorax and tracheae
191. From the following statements select the wrong one [CBSE PMT 2005]  
 (a) Prawn has two pairs of antennae  
 (b) Nematocysts are characteristics of the phylum cnidaria.  
 (c) Millepedes have two pairs of appendages in each segment of the body  
 (d) Animals belonging to phylum porifera are exclusively marine
192. Which structure of man is similar to the spiracle of cockroach [Odisha JEE 2005]  
 (a) Nostril (b) Bronchiole  
 (c) Lungs (d) Alveoli
193. How do you differentiate a butterfly from a moth [KCET 2010]  
 (a) Moth has feathery antennae but butterfly has club shaped antennae  
 (b) Moth has one pair of wings but butterfly has two pairs of wings  
 (c) Moth is diurnal but butterfly is nocturnal  
 (d) Moth has simple eyes but butterfly has compound eyes
194. Tubular heart of cockroach has how many chambers [AFMC 2005]  
 (a) 10 (b) 13  
 (c) 12 (d) 11
195. Which of the following animal belongs to class crustacea [WB JEE 2010]  
 (a) Cockroach (b) Cyclops  
 (c) Grasshopper (d) Mosquito

196. Which of the following statements is correct regarding cockroach [CPMT 2010]

(a) Ventral nerve cord is present  
(b) Spiracles help in excretion  
(c) Phallomere is present in female cockroach  
(d) Compound eye is also called as ocellus

197. Mushroom gland is a part of [CPMT 2010]

(a) Male reproductive system of cockroach  
(b) Female reproductive system of cockroach  
(c) Male reproductive system of rabbit  
(d) Female reproductive system of rabbit

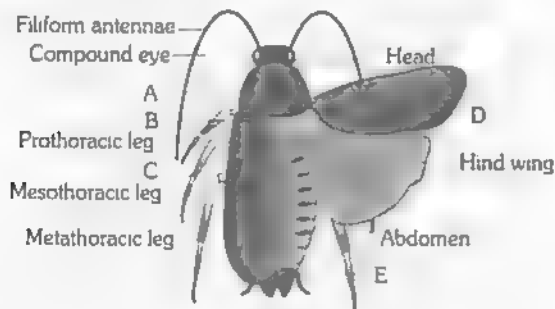
198. What external changes are visible after the last moult of a cockroach nymph [NEET 2013]

(a) Labium develops  
(b) Mandibles become harder  
(c) Anal cerci develop  
(d) Both fore wings with hind wings develop

199. Which one of the following is one of the paths followed by air/O<sub>2</sub> during respiration in an adult male *Periplaneta americana* as it enters the animal body [NEET (Karnataka) 2013]

(a) Spiracle in metathorax, trachea, tracheoles, oxygen diffuses into cells  
(b) Mouth, bronchial tube, trachea, oxygen enters cells  
(c) Spiracles in prothorax, tracheoles, trachea, oxygen diffuses into cells  
(d) Hypopharynx, mouth, pharynx, trachea, tissues

200. See the following figure and identify A to E [NCERT]



	A	B	C	D	E
(a)	Pronotum	Mesothorax	Metathorax	Tegmina	Anal style
(b)	Pronotum	Mesothorax	Metathorax	Tegmina	Anal cerci
(c)	Pronotum	Mesothorax	Metathorax	Tegmina	Sternum
(d)	Pronotum	Mesothorax	Metathorax	Tegmina	Pleura

201. Match Column-I with Column-II for housefly classification and select the correct option using the codes given below [NEET (Phase-II) 2016]

**Column-I**

(A) Family  
(B) Order  
(C) Class  
(D) Phylum

**Codes**

(a) (iv)  
(b) (iii)  
(c) (iii)  
(d) (iv)

**Column-II**

(i) Diptera  
(ii) Arthropoda  
(iii) Muscidae  
(iv) Insecta

(B) (C) (D)  
(ii) (i) (iii)  
(i) (iv) (ii)  
(iii) (iv) (i)  
(iii) (ii) (i)

202. In male cockroaches, sperms are stored in which part of the reproductive system [NEET (Phase-II) 2016]

(a) Vas deferens (b) Seminal vesicles  
(c) Mushroom glands (d) Testes

**Phylum-Mollusca**

1. Which one of the following is not used in organic farming [BHU 2006; AMU (Med.) 2006; CBSE PMT (Pre.) 2010]

(a) Snail (b) Glomus  
(c) Earthworm (d) Oscillatoria

2. The devil fish and sea hare are [NCERT; J & K CET 2008; AMU (Med.) 2012]

(a) Molluscs (b) Crustaceans  
(c) Coelenterates (d) Marine fish and mammal

3. Which one of the following phyla is correctly matched with its two general characteristics [CBSE PMT 2008]

(a) Echinodermata – Pentamerous radial symmetry and mostly internal fertilization  
(b) Mollusca – Normally oviparous and development through a trochophore or veliger larva  
(c) Arthropoda – Body divided into head, thorax and abdomen and respiration by tracheae  
(d) Chordata – Notochord at some stage and separate anal and urinary opening to the outside

4. Foot is displaced to the neighbourhood of mouth and divided into arms in [AIIMS 1999]

(a) *Ostrea* (b) *Pila*  
(c) *Sepia* (d) *Chiton*

5. Most mollusc are [BVP 2003]

(a) Terrestrial (b) Fresh water  
(c) Marine (d) None of these

6. The elephant tusk shell is [RPMT 1999]

(a) *Dentalium* (b) *Nautilus*  
(c) *Limax* (d) *Octopus*

7. Cilia of gills of bivalve molluscs help in [DPMT 2006]

(a) Feeding (b) Digestion  
(c) Reproduction (d) Excretion

8. Which among the following is not a class of phylum mollusca [JIPMER 1993; AFMC 1997]

(a) Gastropoda (b) Trematoda  
(c) Decapoda (d) Both (b) and (c)

9. Which one is not correctly matched [Odisha JEE 2005]

(a) Mollusca – Pseudocoel  
(b) Cnidaria – Nematocyst  
(c) Annelida – Chloragogen cells  
(d) Echinodermata – Water vascular system

10. Osphradium is meant for [CPMT 2005]

(a) Excretion  
(b) Nutrition  
(c) Selection and rejection of food  
(d) Grinding of food

11. Which one belongs to the class of sea hare [MP PMT 1995]

Or

Which of the following belongs to the class gastropoda

[J & K CET 2012]

(a) Sea cow (b) Sea squirt  
(c) Snail (d) Sepia

12. Asymmetry in gastropoda is due to [MH CET 2003]  
(a) Torsion (b) Coiling  
(c) Twisting (d) Abdomen
13. The mollusc which is considered to be a living fossil and also shows characters of annelids like nephridia and internal segmentation is [AIIMS 1993]  
(a) *Pinctada vulgaris* (b) *Nautilus*  
(c) *Neopilina galathea* (d) None of these
14. *Pila* is the example of which class [RPMT 2001]  
(a) Gastropoda (b) Pelecypoda  
(c) Cephalopoda (d) Scaphopoda
15. In which one of the following, the genus name, its two characters and its phylum are not correctly matched, whereas the remaining three are correct [NCERT; CBSE PMT (Pre.) 2012]

	Genus Name		Two characters	Phylum
(a)	<i>Pila</i>	(a)	Body Segmented	Mollusca
		(b)	Mouth with Radula	
(b)	<i>Asterias</i>	(a)	Spiny Skinned	Echinodermata
		(b)	Water vascular system	
(c)	<i>Sycon</i>	(a)	Pore bearing	Porifera
		(b)	Canal system	
(d)	<i>Periplaneta</i>	(a)	Jointed appendages	Arthropoda
		(b)	Chitinous exoskeleton	

16. Visceral mass undergo torsion in [DPMT 2003; AMU (Med.) 2010]  
(a) Gastropoda (b) Cephalopoda  
(c) Palacopoda (d) None of these
17. Cephalopoda is a class of animals in which [MP PMT 1994]  
(a) Notochord extends upto head  
(b) Foot is located on head  
(c) Head is located on foot  
(d) Head is fused with thorax
18. In mollusca, eye is present over a stalk called [CPMT 2000; BHU 2006]  
(a) Ostracum (b) Operculum  
(c) Osphradium (d) Ommatophores
19. "Shell of mollusc is produced by its [BHU 2000; MH CET 2003]  
(a) Radula (b) Thorax  
(c) Mantle (d) Abdomen
20. Which set is correct [CPMT 1998]  
(a) *Euglena*-cilia (b) *Paramecium*-Flagella  
(c) Snail-Foot (d) *Amoeba*-Foot
21. Which of the following is the oldest living fossil [CMC Vellore 1993]  
(a) *Architeuthis* (b) *Neopilina*  
(c) *Nautilus* (d) *Limulus*
22. Which of the following is correct [AIIMS 2001]  
(a) Mollusca - bivalvia-*pila*  
(b) Annelida - hirudinea - silver fish  
(c) Mollusca - cephalopoda - octopus  
(d) Arthropoda - arachnida - grasshopper

23. Phylum mollusca can be distinguished from other invertebrates by the presence of [RPMT 1998; DUMET 2010]  
(a) Bilateral symmetry and exoskeleton  
(b) A mantle and gills  
(c) Shell and non-segmented body  
(d) A mantle and non-segmented body
24. As per classification which of the following is correct [MP PMT 2003]  
(a) *Ascaris*, *Pheretima*, Grasshopper  
(b) *Hydra*, *Pterido*, *Leucosolenia*  
(c) Starfish, Grasshopper, Solen  
(d) *Pila*, *Dentalium*, Octopus
25. Mantle, foot and shell are the character of [BHU 2003]

Or

- Which of the following is a living fossil [MP PMT 2013]  
(a) *Nautilus* (b) *Echinus*  
(c) *Limulus* (d) *Euplectella*
26. Match the columns and choose the correct combination.
- |    |            |    |               |
|----|------------|----|---------------|
| A. | Polychaeta | p. | Scorpion      |
| B. | Trematoda  | q. | <i>Pila</i>   |
| C. | Arachnida  | r. | Liver Fluke   |
| D. | Gastropoda | s. | <i>Nereis</i> |
|    |            | t. | Star Fish     |

[KCET 2003]

- (a) A-s, B-r, C-p, D-q (b) A-q, B-s, C-t, D-p  
(c) A-r, B-s, C-p, D-t (d) A-t, B-q, C-s, D-r
27. Which of the following mollusc is formed by a larva which have torsion [RPMT 2002]  
(a) *Lamelledens* (b) *Pila*  
(c) *Sepia* (d) Octopus
28. Cuttle Fish is a member of  
(a) Mollusca (b) Echinodermata  
(c) Pisces (d) Amphibia
29. A wood boring mollusca/Shipworm is  
(a) *Chiton* (b) *Teredo*  
(c) *Limax* (d) *Patella*
30. Radula is found in [WB JEE 2010]  
(a) *Pila* sp (b) *Chiton* sp  
(c) *Lamellidens* sp (d) *Pinctada* sp
31. Haemocyanin, the blue colouring pigment of molluscan blood contains  
(a) Iron (b) Magnesium  
(c) Copper (d) Manganese
32. Filter feeding occurs in  
(a) *Dentalium* (b) *Unio*  
(c) *Pila* (d) *Amoeba*
33. An animal without segmentation is  
(a) Tapeworm (b) Earthworm  
(c) Glow Worm (d) Shipworm
34. Closed circulatory system occurs in [CBSE PMT 1994]  
(a) Snail (b) Cockroach  
(c) Cuttle Fish (d) All the above
35. *Pila* shows summer [APMEE 1995]  
(a) Hibernation (b) Aestivation  
(c) Emigration (d) Immigration
36. Octopus, Squid and Cuttle Fish belong to class [BHU 1998; RPMT 2001; AFMC 2001]  
(a) Cephalopoda (b) Apoda  
(c) Decapoda (d) Scaphopoda

37. Which one occurs in molluscs but not in echinoderms [AFMC 2001; DUMET 2010]  
(a) Flame cells (b) Malpighian tubules  
(c) Kidney (d) None of the above
38. In which of the following group of animals the trochophore larva becomes the veliger larva [MP PMT 2013]  
(a) Mollusca (b) Arthropoda  
(c) Annelida (d) Platyhelminthes
39. Shell is internal in [Pb. PMT 1999]  
(a) *Loligo* (b) *Chiton*  
(c) *Dentalium* (d) *Unio*
40. *Sepia* and *Octopus* swim swiftly by means of [MP PMT 2013]  
(a) Arms  
(b) Lateral fins  
(c) Suckers  
(d) Jet propulsion through siphon
41. Ammonites are fossil shell remains of [CPMT 2000]  
(a) Pelecypods (b) Cephalopods  
(c) Gastropods (d) Scaphopods
42. Scaphopoda are commonly called [CPMT 2000]  
(a) Whelks (b) Periwinkles  
(c) Oysters (d) Tusk shells

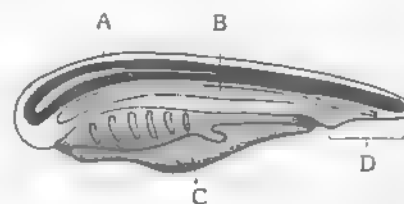
### Phylum-Echinodermata

1. Aristotle's lantern is found in [JIPMER 1993; RPMT 1999, 2000; AFMC 2001; AIIMS 2001]  
(a) Jelly fish (b) Sea anemone  
(c) Sea lily (d) Sea urchin
2. Secondary radial symmetry is found in [MP PMT 2009]  
(a) Cnidaria (b) Jelly fish  
(c) Echinodermata (d) Hemichordata
3. Which trait is not the characteristic of echinodermata [Odisha JEE 2009]  
(a) Water vascular system  
(b) Trochophore larva  
(c) Aristotle's lantern  
(d) Radial and indeterminate cleavage
4. Main function of pedicellariae in *Asterias* is [CPMT 1999]  
(a) Digestion  
(b) Excretion  
(c) Respiration  
(d) Capture of prey and removal of debris
5. Sea lilies are the members of class [CBSE PMT 1993]  
(a) Ophiuroidea (b) Asteroidea  
(c) Crinoidea (d) Echinoidea
6. In Ophiuroidea, branched arms are seen in [EAMCET 2009]  
(a) *Gorgonocephalus* (b) *Clypeaster*  
(c) *Salmacis* (d) *Gorgonia*
7. The Presence of tube feet is the characteristic feature of phylum [NCERT; Kerala PMT 2009; AMU (Med.) 2010]  
(a) Arthropoda (b) Annelida  
(c) Nematelminthes (d) Echinodermata  
(e) Mollusca
8. In which phylum is water vascular system found [NCERT; MP PMT 1999, 2011; BHU 2008; WB JEE 2008, 10]  
(a) Protozoa  
(b) Arthropoda  
(c) Porifera  
(d) Echinodermata (Sea-cucumber)
9. Starfish belongs to class [KCET 1998; BHU 2000, 02; CBSE PMT 2002; MP PMT 2012]  
(a) Pisces (b) Cephalopoda  
(c) Asteroidea (d) Ophiuroidea
10. Ambulacral grooves are absent in the living forms of the class [Pb. PMT 1999; AIIMS 2002]  
(a) Crinoidea (b) Ophiuroidea  
(c) Asteroidea (d) Echinodermata
11. Aristotle's lantern is a characteristic of the following class of echinodermata [KCET 1998; BVP 2001]  
(a) Echinoidea (b) Ophiuroidea  
(c) Holothuroidea (d) Asteroidea
12. A special feature of Evisceration (Autoformy) is found in [CPMT 1998]  
(a) Chordata (b) Echinodermata  
(c) Annelida (d) Coelentrata
13. Enterocoelic type of coelom is present in the [CPMT 1999; Pb. PMT 2004]  
(a) Echinodermata (b) Mollusca  
(c) Arthropoda (d) Chordata
14. Animals of which group are not fresh water [RPMT 1999; DPMT 2003]  
(a) Crustacea (b) Insecta  
(c) Echinodermata (d) Sponge
15. Which phylum belongs to *Duterostomia* [EAMCET 1998; CPMT 1999; BHU 2001; CBSE PMT 2001]  
(a) Echinodermata (b) Mollusca  
(c) Arthropoda (d) Annelida
16. An animal that transforms from bilateral to radial symmetry in its life history is [KCET 1998; HP PMT 2005; Kerala CET 2005; Odisha JEE 2012]  
(a) Hydra (b) Obelia  
(c) Starfish (d) Sponge
17. Absence of excretory organs, great power of regeneration and exclusively marine animals belong to the phylum [NCERT; AIIMS 1993; BVP 2004; AIEEE Pharmacy 2004; Odisha JEE 2012]  
(a) Mollusca (b) Echinodermata  
(c) Fishes (d) Arthropoda
18. The pentaradial symmetry is seen in [Odisha JEE 2011]  
(a) Echinodermata (b) Arthropoda  
(c) Mollusca (d) Annelida
19. Mark the correct one [CPMT 1996]
- | Phylum            | Class         | Example       |
|-------------------|---------------|---------------|
| (a) Annelida      | Oligochaeta   | <i>Nereis</i> |
| (b) Mollusca      | Pelecypoda    | Cuttle fish   |
| (c) Reptillia     | Ophidia       | Lizard        |
| (d) Echinodermata | Holothuroidea | Cucumaria     |
20. Which one of the following pairs of animals is correctly matched with the kind of their body symmetry [AIEEE Pharmacy 2003]  
(a) *Hydra* and shark - Bilateral symmetry  
(b) Tapeworm and octopus - Radial symmetry  
(c) *Amoeba* and sea urchin - Asymmetry  
(d) Jellyfish and starfish - Radial symmetry
21. Absence of head, unsegmented body and endoskeleton of dermal calcareous plate are the characters of [J & K CET 2005]  
(a) Mollusca (b) Arthropoda  
(c) Echinodermata (d) None of these

22. An animal phylum having radially symmetrical adults but bilateral symmetrical larvae is [NCERT; BVP 2001; DPMT 2004; CBSE PMT 2004; Kerala PMT 2008; KCET 2012]  
 (a) Porifera (b) Coelenterata  
 (c) Echinodermata (d) Annelida
23. Cephalization is absent in  
 (a) Molluscs (b) Arthropods  
 (c) Both (a) and (b) (d) Echinoderms
24. Which is unrelated [RPMT 1996]  
 (a) Sea Cucumber (b) Sea Star  
 (c) Sea Urchin (d) Sea Squid
25. Echinodermata is a group of animals which are [MP PMT 2004]  
 (a) Coelomate, homy, marine  
 (b) Coelomate, spiny, marine  
 (c) Acoelomate, spiny, fresh water  
 (d) Joint legged, marine
26. Aristotle's lantern is connected with [AIIMS 1999; APME 2002]  
 (a) Respiration (b) Mastication  
 (c) Excretion (d) Support
27. Echinoderms are headless, brainless and heartless. Yet they are placed at the top of invertebrates because of presence of [MP PMT 2000]  
 (a) Enterocoel  
 (b) Exclusive marine forms  
 (c) High power of regeneration  
 (d) Great power of reproduction
28. Tube feet are the characteristic structures of [CBSE PMT 2000; MHCET 2001; BHU 2005; CPMT 2009; Odisha JEE 2010]  
 (a) Jellyfish (b) Cuttlefish  
 (c) Starfish (Echinodermata) (d) Crayfish
29. Match the animals list with names under Column-I with the animals listed with regular zoological name given under Column-II; choose the answer which gives the correct combination of the alphabets of the two columns
- | Column-I<br>Animals with<br>common name |            | Column-II<br>Animals with<br>zoological name |             |
|---|------------|--|-------------|
| A.                                      | Starfish   | p.   | Sepia       |
| B.                                      | Jellyfish  | q.   | Astropecten |
| C.                                      | Devilfish  | r.   | Aurelia     |
| D.                                      | Cuttlefish | s.   | Octopus     |
- [KCET 2000, 09]  
 (a) A = r, B = s, C = p, D = q  
 (b) A = r, B = p, C = s, D = q  
 (c) A = q, B = r, C = s, D = p  
 (d) A = q, B = p, C = s, D = r
30. Antedon belongs to the class [AIIMS 2000]  
 (a) Crinoidea (b) Asteroidea  
 (c) Ophiuroidea (d) Echinoidea
31. Basket star belongs to class [AIIMS 1999; AFMC 2000]  
 (a) Ophiuroidea (b) Echinoidea  
 (c) Asteroidea (d) Crinoidea
32. Box like calcareous test occurs in [HPMT 2001]  
 (a) Sea Lily (b) Sea Star  
 (c) Sand Dollar (d) Sea Cucumber
33. In which class of echinodermata stalk is found for attachment with substratum [RPMT 2001]  
 (a) Asteroidea (b) Echinoidea  
 (c) Ophiuroidea (d) Crinoidea
34. Bipinnaria is the larva of [BHU 2001; Odisha JEE 2004]  
 (a) Pila (b) Lemniscidens  
 (c) Sepia (d) Star fish (Asteroidea)
35. Which one of the following statement is true about an organism and its classification [AIEEE Pharmacy 2004; AMU (Med.) 2005]  
 (a) Blue green alga is kind of fungus  
 (b) Sea horse is closely related to dolphin  
 (c) Maiden hair tree is a kind of angiosperm  
 (d) Sea lily is a kind of echinoderm
36. In echinodermata, tube feet are related with [BVP 2003]  
 (a) Excretory system (b) Ambulacral system  
 (c) Reproductive system (d) Respiratory system

### Phylum-Chordata

1. Which one of the following pairs of animals comprises 'jawless fishes' [NCERT; CBSE PMT 2009]  
 (a) Lampreys and eels (b) Mackerals and Rohu  
 (c) Lampreys and hag fishes (d) Guppies and hag fishes
2. The number of gills present in Osteichthyes is [Kerala PMT 2008]  
 (a) 2 pairs (b) 6 ~ 15 pairs  
 (c) 5 pairs (d) 4 pairs  
 (e) 12 pairs
3. At retrogressive metamorphosis the urochordate larva [AFMC 2006]  
 (a) Loss notochord  
 (b) Loss tail  
 (c) Experience reduction of nervous system to a visceral ganglion  
 (d) All of the above
4. Animals belonging to phylum Chordata are fundamentally characterized by the presence of structure noted as A, B, C and D. Identify the names of A, B, C and D [NCERT]



- (a) A – Nerve cord, B – Gill slits, C – Notochord, D – Post-anal part  
 (b) A – Nerve cord, B – Notochord, C – Post-anal part, D – Gill slits  
 (c) A – Nerve cord, B – Notochord, C – Gill slits, D – Post-anal part  
 (d) A – Notochord, B – Nerve Cord, C – Gill Slits, D – Post-anal part
5. In which of the following jaws are found [RPMT 1999]  
 (a) Herdmania (b) Fish  
 (c) Petromyzon (d) Amphioxus

6. Temperature changes in the environment affect most of the animals which are [CBSE PMT 1999; CPMT 2001]
  - (a) Aquatic (b) Desert living
  - (c) Poikilothermic (d) Homoiothermic
7. The animal who possesses notochord throughout life is [EAMCET 1998; CPMT 1999; CBSE PMT 2000; MH CET 2003; BHU 2005; Odisha JEE 2010]
 

Or

Which of the following animals is not a vertebrate [NCERT]

  - (a) Fish (b) *Amphioxus*
  - (c) Bird (d) Snake
8. Which of the following statements is / are not true
  - A. In Urochordata, notochord is present only in larval tail.
  - B. In Cephalochordata, notochord extends from head to tail region.
  - C. Branchiostoma belongs to Hemichordata
  - D. Only one Class of living members, Class Cyclostomata represents the Super Class Agnatha

[NCERT; Kerala PMT 2006]

  - (a) A, B and D only (b) C, D and A only
  - (c) C only (d) A and D only
  - (e) C and D only
9. Blood vascular system in hemichordata is [AFMC 2006]
  - (a) Open (b) Reduced
  - (c) Closed (d) Absent
10. The most important distinctive character of chordata is the presence of [CBSE PMT 1991]
  - (a) Vertebral column (b) Hairy skin
  - (c) Notochord (d) All the above
11. Retrogressive metamorphosis is found in [RPMT 1999, 2006; WB JEE 2010]
  - (a) *Balanoglossus* (b) *Branchiostoma*
  - (c) *Herdmania* (Urochordata) (d) All of these
12. The lamprey (*Petromyzon*) is included in the same taxonomic class as the
  - (a) Chamaeleon (*Anolis*) (b) Hag fish (*Myxine*)
  - (c) Salamander (*Ambystoma*) (d) Lung fish (*Neoceratodus*)
13. The portal system seen in all vertebrates is [JIPMER 1993]
  - (a) Hepatic (b) Renal
  - (c) Both (a) and (b) (d) Pulmonary
14. Which one of the following is not a characteristic feature of the sub phylum vertebrata [NCERT; Kerala PMT 2007]
  - (a) Dorsal tubular nerve cord
  - (b) Ventral muscular heart
  - (c) Presence of notochord in the adult
  - (d) Presence of kidneys
  - (e) Two pairs of lateral appendages, fins or limbs
15. Notochord is restricted to the anterior part of body proboscis in animals of which group [RPMT 1995]
  - (a) Hemichordata (b) Urochordata
  - (c) Cephalochordata (d) Chordata
16. Animals having a built-in thermostat to maintain constant body temperature are known as [KCET 1999; CPMT 2003; BHU 2006; AFMC 2012]
  - (a) Biothermic (b) Poikilothermic
  - (c) Oligothermic (d) Homoeothermic
17. Which of the following groups has no member having gliding or flying appendages
  - (a) Arthropoda (b) Cyclostomata
  - (c) Mammals (d) Fishes
18. In some chordates, the notochord is modified as the vertebral column. Such animals are called vertebrates. Which one of the following statements make sense [NCERT; KCET 2003, 11]
  - (a) All chordates are vertebrates but all vertebrates are not chordates
  - (b) All vertebrates are chordates and all chordates are vertebrates
  - (c) All vertebrates are chordates but all chordates are not vertebrates
  - (d) Chordates are not vertebrates and vertebrates are not chordates
19. *Petromyzon* belongs to [MH CET 2004]
  - (a) Agnatha (b) Gnathostomata
  - (c) Protochordata (d) Euchordata
20. The echinoderms, hemichordates and chordates had which of the following larva as common ancestral form [APMEE 1996; BHU 1999; CBSE PMT 2001]
  - (a) Tomaria (b) Trochophore
  - (c) Dipleurula (d) Bipinnaria
21. Which among the following is the only vertebrate osmoconformer [DPMT 2004]
  - (a) Rabbit (b) Hagfish
  - (c) Bird (d) None of these
22. Which one of the following feature is found in chordates but not in non-chordates [KCET 2007]
  - (a) Gills (b) Spiracles
  - (c) Post anal tail (d) Chitinous exoskeleton
23. Which of the following show relationship of echinoderms and chordates [DPMT 1993]
  - (a) *Balanoglossus* (b) *Archaeopteryx*
  - (c) *Peripatus* (d) None of these
24. Crocodile and penguin are similar to Whale and Dogfish in which one of the following features [NCERT; CBSE PMT (Malna) 2010]
  - (a) Possess a solid single stranded central nervous system
  - (b) Lay eggs and guard them till they hatch
  - (c) Possess bony skeleton
  - (d) Have gill slits at some stage
25. Which of the following sets of animals belong to class cyclostomata [NCERT; DPMT 1993; BHU 2000; J & K CET 2008]
  - (a) *Herdmania* and *petromyzon*
  - (b) *Petromyzon* and *myxine*
  - (c) *Amphioxus* and *balanoglossus*
  - (d) *Herdmania* and *myxine*
26. The jawless vertebrate is [Kerala PMT 2004]
 

Or

A jawless fish, which lays eggs in fresh water and whose ammocoetes larvae after metamorphosis return to the ocean, is [AIPMT 2015]

  - (a) Crocodile (b) *Loris*
  - (c) *Hyla* (d) Fox
  - (e) *Petromyzon*
27. *Herdmania* belongs to which subphyla [DPMT 2004]
  - (a) Cephalochordata (b) Hemichordata
  - (c) Urochordata (d) Protochordata

28. All chordates at one or the other stage possess

[MP PMT 2004]

- (a) Vertebral column
- (b) Pharyngeal gills-slits
- (c) Two pairs of pentadactyle limb
- (d) A movable jaw

29. Which one feature is common to *Amphioxus*, frog, sea horse and crocodile

[AIIEE Pharmacy 2003]

- (a) Pharyngeal gill slits, at least in the developmental stages
- (b) A three-chambered heart
- (c) Dorsal solid nerve chord
- (d) Skeleton formed of cartilage and bones

30. Larva of *Balanoglossus* is

- (a) Tornaria
- (b) Muller's larva
- (c) Kentrogen larva
- (d) Tadpole

31. Which of the following is a distinct character

[Wardha 2005]

- (a) Chorda dorsalis
- (b) Cephalization
- (c) Claws
- (d) Pharyngotomy

32. Vertebral column is derived from

- (a) Notochord
- (b) Dorsal nerve cord
- (c) Ventral nerve cord
- (d) Outgrowth of cranium

33. Match items in column I with those give in column II

	Column I		Column II
(A)	Limbless reptile	(i)	Lamprey
(B)	Jawless vertebrate	(ii)	Salamander
(C)	Amphibian	(iii)	Snake
(D)	Cartilaginous fish	(iv)	Shark
(E)	Flightless bird	(v)	Ostrich

[Kerala CET 2005]

- (a) (A) – (i), (B) – (ii), (C) – (iii), (D) – (iv), (E) – (v)
- (b) (A) – (ii), (B) – (i), (C) – (iii), (D) – (iv), (E) – (v)
- (c) (A) – (iii), (B) – (i), (C) – (ii), (D) – (iv), (E) – (v)
- (d) (A) – (v), (B) – (ii), (C) – (iii), (D) – (iv), (E) – (i)

34. Common characteristic of all vertebrates without exception is

[CBSE PMT 1994]

- (a) Exoskeleton
- (b) Presence of well developed skull
- (c) Two pairs of functional appendages
- (d) Division of body into head, neck, trunk and tail

35. Which of the following is the smallest taxonomic group of animals having a cranium, vertebral column, ventral heart, pulmonary respiration and two pairs of limbs

[AFMC 1998]

- (a) Gnathostomata
- (b) Tetrapoda
- (c) Vertebrata
- (d) Chordata

36. The vertebrate does not have

[Odisha JEE 2011]

- (a) Epidermal scale
- (b) Claw
- (c) Tail
- (d) Cnidoblast

37. Ancestors of cyclostomes are

[BHU 1993]

- (a) Myxinoidea
- (b) Arthropods
- (c) Ostracoderms
- (d) Urochordates

38. See the following diagram and identify the name of the animal and the phylum to which it belong correctly

[NCERT]



- (a) *Nereis*, Annelida
- (b) *Balanoglossus*, Urochordata
- (c) *Balanoglossus*, Cephalochordata
- (d) *Balanoglossus*, Hemichordata

39. Birds and mammals have

[NCERT; MH CET 2000]

- (a) Three chambered heart
- (b) Four chambered heart
- (c) Six chambered heart
- (d) None of the above

40. Homeothermic animals is

[MH CET 2000]

- (a) Toad
- (b) Lizard
- (c) Rabbit
- (d) Frog

41. Which of the following are Anamniotes

[RPMT 2001]

- (a) Chondrichthyes, Osteichthyes, Amphibia
- (b) Reptilia, Aves, Amphibia
- (c) Amphibia, Aves, Mammals
- (d) Reptilia, Mammals, Aves

42. In Urochordata notochord is found in

[RPMT 2001]

- (a) Head of adult
- (b) Tail of adult
- (c) Tail of larva
- (d) Test of adult

43. In which of the following notochord is absent

[RPMT 2001]

- (a) Adult *Herdmania* and *Balanoglossus*
- (b) Adult *Herdmania* and adult *Branchiostoma*
- (c) Larva of *Herdmania* and *Branchiostoma*
- (d) Larva of *Herdmania* and *Balanoglossus*

44. The correct classification of *Balanoglossus* is

[RPMT 2001]

- (a) Chordata → Vertebrata → Enteropneusta
- (b) Chordata → Vertebrata → Pterobranchia
- (c) Chordata → Hemichordata → Pterobranchia
- (d) Chordata → Hemichordata → Enteropneusta

45. In which of the following the notochord is present in embryonic stage

[CBSE PMT 2002]

- (a) Vertebrates
- (b) Some chordates
- (c) All chordates
- (d) Non-chordates



46. Which of the following is not a character of Chordata

[NCERT; MH CET 2002; CPMT 2010]

- (a) Dorsal tubular nerve cord
- (b) Pharyngeal gill slits
- (c) Presence of notochord
- (d) Presence of spinal cord

47. Which animal is "Non-chordate-prot chordata"

[RPMT 2002; CPMT 2010]

Or

Which of the following is a hemichordate [Odisha JEE 2010]

- (a) Herdmania
- (b) Balanoglossus
- (c) Branchiostoma
- (d) Botryllus

48. Mode of feeding in tunicates is

[EAMCET 2002]

- (a) Parasitic
- (b) Macrophagus
- (c) Ciliary filter
- (d) Myxotrophic

49. Which one of the following statements is totally wrong about the occurrence of notochord, while the other three are correct

[NCERT; CBSE PMT (Mains) 2011]

- (a) It is absent throughout life in humans from the very beginning
- (b) It is present throughout life in *Amphioxus*
- (c) It is present only in larval tail in Ascidians
- (d) It is replaced by a vertebral column in adult frog

50. Match the following and select the correct option

A.	Cyclostomes	1	Hemichordata
B.	Aves	2	Urochordata
C.	Tunicates	3	Agnatha
D.	<i>Balanoglossus</i>	4	Pisces
E.	Osteichthyes	5	Tetrapod

[Kerala PMT 2011]

- (a) A-1, B-2, C-3, D-4, E-5
- (b) A-2, B-3, C-4, D-1, E-5
- (c) A-3, B-5, C-2, D-1, E-4
- (d) A-3, B-1, C-5, D-2, E-4
- (e) A-5, B-3, C-2, D-1, E-4

51. *Echidna* and *Ornithorhynchus* are the connecting links between

[AIIMS 2009]

- (a) Amphibians and aves
- (b) Mammals and amphibians
- (c) Reptiles and mammals
- (d) Reptiles and amphibians

52. Column I contains larval stages and column II contains the groups to which they belong. Match them correctly and choose the right answer

	Column I		Column II
A.	Planula	1.	Annelida
B.	Tomaria	2.	Mollusca
C.	Trochophore	3.	Arthropoda
D.	Bipinnaria	4.	Chordata
E.	Glochidium	5.	Echinodermata
		6.	Coglenenterata

[KCET 2011]

(a) A-6, B-4, C-1, D-5, E-2

(b) A-2, B-5, C-1, D-4, E-6

(c) A-5, B-4, C-3, D-2, E-1

(d) A-4, B-3, C-2, D-1, E-5

53. Stomochord is found in

[Odisha JEE 2011]

- (a) Urochordata
- (b) Hemichordata
- (c) Cephalochordata
- (d) Both (a) and (b)

54. Match the name of the animal (column I), with one characteristics (column II), and the phylum/class (column III) to which it belongs

[NEET 2013]

	Column I	Column II	Column III
(a)	<i>Adamsia</i>	Radially symmetrical	Porifera
(b)	<i>Petromyzon</i>	Ectoparasite	Cyclostomata
(c)	<i>Ichthyophis</i>	Terrestrial	Reptilia
(d)	<i>Limulus</i>	Body covered by chitinous exoskeleton	Pisces

### Super Class-Pisces

1. Lateral line system is present in

[BHU 1995; Wardha 2005]

- (a) Fish
- (b) Frog
- (c) Reptiles
- (d) Man

2. Which one of the following is a cartilaginous fish

- (a) Silver fish
- (b) Dog fish
- (c) Cray fish
- (d) Star fish

3. Which of the following has a cartilaginous endoskeleton

[RPMT 1995]

- (a) Elasmobranch
- (b) Dipnoi
- (c) Mollusca
- (d) Bony fishes

4. Electric organs are found in

[MP PMT 1995;

EAMCET 1998; BHU 1999; MH CET 2000; BVP 2003]

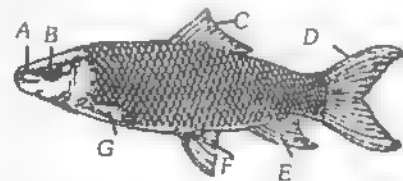
- (a) Sharks
- (b) Porpoises
- (c) Goldfish
- (d) Rays (Torpedo)

5. A fish is characterised by the presence of

- (a) Dermal scales
- (b) Paired fins
- (c) Pharyngeal gills
- (d) All the above

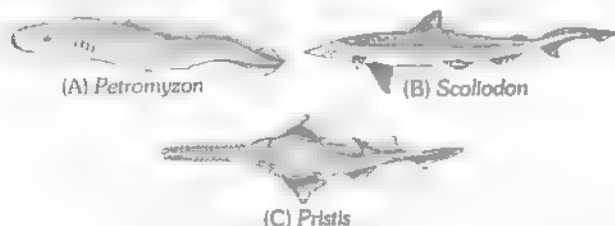
6. Which one of the following is an example of a lung-fish  
[AIIEE Pharmacy 2003]  
(a) Scoliodon (b) Coelacanth  
(c) Labeo (d) Protopterus
7. Which one of the following is exotic Indian fish  
[CBSE PMT 1996]  
(a) *Clarias* (b) *Labeo*  
(c) *Cypris* (d) *Dephnia*
8. Which of the following represents the correct combination without any exception  
[AIPMT (Cancelled) 2015]
- |     | Characteristics   | Class          |
|-----|---|----------------|
| (a) | Mouth ventral; gills without operculum; skin with placoid scales; persistent notochord                            | Chondrichthyes |
| (b) | Sucking and circular mouth; jaws absent, integument without scales; paired appendages                             | Cyclostomata   |
| (c) | Body covered with feather; skin moist and glandular; fore-limbs form wings; lungs form wings, lungs with air sacs | Aves           |
| (d) | Mammary gland; hair on body; pinnae; two pairs of limbs   | Mammalia       |
9. In sharks, one of the following is absent  
[NCERT; J & K CET 2008]  
(a) Claspers  
(b) Placoid scales  
(c) Cartilaginous endoskeleton  
(d) Air bladder
10. Which of the following fish first injures its prey [AFMC 2008]  
(a) *Clarius* (b) *Gambusia*  
(c) *Heteropneustes* (d) *Solea*
11. Which of the following animals is a fish [Odisha JEE 2009]  
(a) Shark (b) Star fish  
(c) Silver fish (d) Jelly fish
12. *Pristis* belongs to the class [JIPMER 1994]  
(a) Dipnoi (b) Telostomi  
(c) Elasmobranchii (d) Holocephali
13. Bony plates and scutes are found in addition to scales in  
(a) Hag fish (b) Eel  
(c) Flying fish (d) Sea horse
14. Which one of the following pairs of animals are similar to each other pertaining to the feature stated against them  
[NCERT; CBSE PMT (Mains) 2012]  
(a) *Pteropus* and *Ornithorhynchus*-Viviparity  
(b) Garden lizard and Crocodile-Three chambered heart  
(c) *Ascaris* and *Ancylostoma*-Metameric segmentation  
(d) Sea horse and Flying fish-Cold blooded (poikilothermal)
15. Ampullae of Lorenzini are present in [DUMET 2009]  
(a) Fish (b) Lizard  
(c) Frog (d) Rabbit
16. True fishes possess gills and fins. Which of the following is not a true fish [DPMT 1993; MP PMT 1994]  
(a) Silver fish (*Lepisma*)  
(b) Gold fish (*Carassius*)  
(c) Silver carp (*Hythalamictyes*)  
(d) Sea horse (*Hippocampus*)
17. Which of following is a true fish  
[Bihar MDAT 1995; JIPMER (Med.) 2002]  
(a) Dog fish (b) Cat fish  
(c) Both (a) and (b) (d) Whale
18. Which of the following is a viviparous fish [DUMET 2009]  
(a) *Exocoetus* (b) *Gambusia*  
(c) *Clarias* (d) *Labeo*
19. Heart of fishes is [Kerala PMT 2009]  
(a) One chambered (b) Two chambered  
(c) Three chambered (d) Four chambered
20. *Hippocampus* (Sea Horse) belongs to the class  
[HP PMT 2005]  
(a) Agnatha (b) Chondrichthyes  
(c) Osteichthyes (d) Mammalia
21. Fishes are [RPMT 1999]  
(a) Homiothermic (b) Poikilothermic  
(c) Both (a) and (b) (d) None of these
22. Which of the following is characteristic feature of fishes  
[KCET 2001; CBSE PMT 2002; Pb. PMT 2004; Odisha JEE 2012]  
(a) Tail and venous heart (b) Venous heart and gills  
(c) Epidermal scales and tail (d) Epidermal scales and gills
23. Sea horse is [NCERT; RPMT 1995; CPMT 2003]  
(a) Fish (b) Reptile  
(c) Mammal (d) Bird
24. Placoid scales are found in [BHU 2008]  
(a) Reptiles (b) Bony fishes  
(c) Cartilaginous fishes (d) Amphibians
25. Swim bladder is present in [BHU 2008]  
(a) *Scoliodon* (b) *Labeo*  
(c) *Chimaera* (d) *Trygon*
26. Connecting link between cartilaginous and bony fishes is [BHU 2008]  
(a) Catla (b) *Chimaera*  
(c) *Protopterus* (d) *Torpedo*

27. With respect to mode of excretion, which type of organism bony fishes are [GUJCET 2007]  
(a) Osmoconformers (b) Ammonotelic  
(c) Uricotelic (d) Uriotelic
28. Which fins are paired in fishes [BHU 2001]  
(a) Dorsal fin and anal fin (b) Pelvic fin and ventral fin  
(c) Pectoral fin and pelvic fin (d) Caudal fin and dorsal fin
29. Salmon is [DPMT 2004]  
(a) Anadromous fish (b) Catadromous fish  
(c) Mollusca (d) Insect
30. Choose the cat fish from the following [KCET 2004]  
(a) *Cirrhina mrigala* (b) *Wallago attu*  
(c) *Labeo rohita* (d) *Catla catla*
31. At present, the Dipnoans are distributed over [Manipal 2003]  
(a) Europe and North America  
(b) Latin America and Australia  
(c) Europe and Latin America  
(d) North America and Australia
32. One of the world's most poisonous fish toxins is released by [AIIMS 2012]  
(a) Clown fish (b) Sword fish  
(c) Eel fish (d) Puffer fish
33. *Hemicyclaspis* belongs to the class [EAMCET 2003]  
(a) Pisces (b) Ostracodermi  
(c) Cyclostomata (d) Gnathostomata
34. Association between suckerfish (*Remora*) and shark is  
(a) Symbiosis (b) Commensalism  
(c) Parasitism (d) Predation
35. Which one is a true fish  
(a) Whale (b) Cuttlefish  
(c) Silverfish (d) Flying fish
36. Anadromous fishes move [CBSE PMT 1992]  
(a) From sea to freshwater (b) From sea to estuary  
(c) From river to sea (d) From estuary to sea
37. Cartilaginous fishes do not have [CBSE PMT 1992]  
(a) Operculum (b) Scales  
(c) Gill stits (d) Pelvic fins
38. Which is viviparous [JIPMER 1998]  
(a) Bony fish (b) Lung fish  
(c) Frog (d) Shark
39. Common name of fish *Anguilla* is [MP PMT 1994; AFMC 2009]  
(a) Eel (b) Rohu  
(c) Hilsa (d) Bombay duck
40. In fishes the kidney is [AFMC 1993]  
(a) Pronephros (b) Mesonephros  
(c) Metanephros (d) Holonephros
41. In one of the following fishes, the dorsal fin is modified into suckers [EAMCET 1999]  
(a) *Torpedo* (b) *Echeneis*  
(c) *Hippocampus* (d) *Neoceratodus*
42. Presence of claspers is an important character in [EAMCET 1999]  
(a) *Sphyrna* (b) *Echeneis*  
(c) *Hippocampus* (d) *Exocoetus*
43. Freshwater bony fishes maintain water balance by [BHU 2002]  
(a) Excreting hypotonic urine  
(b) Excreting salt across their gills  
(c) Drinking small amount of water  
(d) Excreting waste in the form of uric acid
44. Salmon belongs to the group of [BHU 1998; AMU (Med.) 2002]  
(a) Bony fishes (b) Cartilaginous fishes  
(c) Cod fishes (d) Trout fishes
45. One of the following is known as 'oil sardine' [EAMCET 1999]  
(a) *Atropus surtensis* (b) *Harpodon recherius*  
(c) *Sardinella longiceps* (d) *Rastrelliger kanegunta*
46. Which of the following is a migratory fish [AFMC 2001]  
(a) Shark (b) Salmon  
(c) Carp (d) Ribbon fish
47. Similarity between fish and tadpole is [BVP 2001]  
(a) Legs (b) Fins  
(c) Lateral line (d) Scales
48. Which of the following is known as living fossil [MP PMT 2001, 03]  
(a) *Lepidostren* (b) *Lepidosteus*  
(c) *Latimeria* (d) *Neoceratodus*
49. The aquatic organism with prehensile tail is [EAMCET 2002]  
(a) *Macaca* (b) *Chameleon*  
(c) *Exocoetus* (d) *Hippocampus*
50. Cartilaginous fishes belong to the class [NCERT; HP PMT 2005]  
(a) Chondrichthyes (b) Osteichthyes  
(c) Agnatha (d) None of these
51. Which of the following is a catadromous fish [WB JEE 2010]  
(a) *Hilsa sp* (b) *Mystus sp*  
(c) *Anguilla sp* (d) *Channa sp*
52. The diagram of *labeo rohita* is given below. Identify the parts labelled A, B, C, D, E, F, G [KCET 2010]

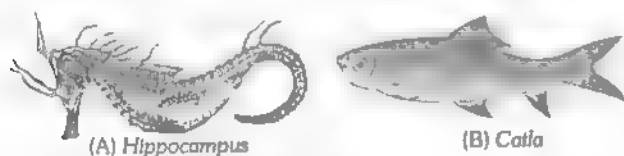


	A	B	C	D	E	F	G
(a)	Stimulus Receptor	Eye	Sensory nerve	Motor nerve	Effector	Pectoral fin	Pelvic fin
(b)	Nostril	Eye	Anal fin	Caudal fin	Dorsal fin	Pectoral fin	Pelvic fin
(c)	Nostril	Eye	Dorsal fin	Caudal fin	Anal fin	Pelvic fin	Pectoral fin
(d)	Nostril	Eye	Dorsal fin	Caudal fin	Pectoral fin	Anal fin	Pelvic fin

53. Which one of the following groups of animals is correctly matched with its one characteristic feature without even a single exception [NCERT; CBSE PMT (Pre.) 2011]
- Mammalia : give birth to young ones
  - Reptilia : possess 3-chambered heart with one incompletely divided ventricle
  - Chordata : possess a mouth provided with an upper and a lower jaw
  - Chondrichthyes : possess cartilaginous endoskeleton
54. What will you look for to identify the sex of the following [NCERT; CBSE PMT (Pre.) 2011]
- Male shark – Claspers borne on pelvic fins
  - Female Ascaris – Sharply curved posterior end
  - Male frog – A copulatory pad on the first digit of the hind limb
  - Female cockroach – Anal cerci
55. Scientific name of rohu is [Odisha JEE 2011]
- Anabas testudineus
  - Catla catla
  - Labeo rohita
  - Naja naja
56. Air bladder is present in [DUMET 2010]
- Chondrichthyes
  - Star fishes
  - Actinopterygii
  - Flying fishes
57. Jaw of shark contains [AMU (Med.) 2012]
- Thecodont teeth
  - Acrodont teeth
  - Pleurodont teeth
  - None of these
58. See the following figures and click the correct option with their respective classes [NCERT]



- A – Osteichthyes, B – Chondrichthyes, C – Cyclostomata
  - A – Osteichthyes, B – Chondrichthyes, C – Osteichthyes
  - A – Osteichthyes, B – Chondrichthyes, C – Chondrichthyes
  - A – Cyclostomata, B – Chondrichthyes, C – Chondrichthyes
59. See the following figures and select the right option with their respective classes [NCERT]

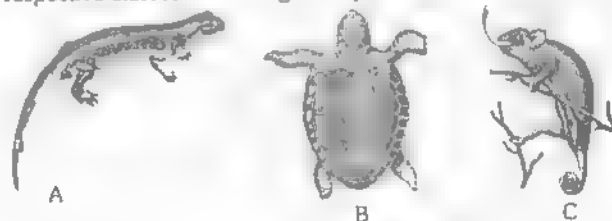


- A – Cartilage fish, B – Hag fish
- A – Cartilage fish, B – Cartilage fish
- A – Bony fish, B – Cartilage fish
- A – Bony fish, B – Bony fish

60. The marine fish among the following varieties is [MHCET 2015]
- Stromateus
  - Labeo
  - Cirrhina
  - Catla
61. Among the following edible fishes which one is a marine fish having rich source of omega-3 fatty acids [NEET (Phase-II) 2016]
- Mackerel
  - Mystus
  - Mangur
  - Mrigala
62. Choose the correct statement [NEET (Phase-II) 2016]
- All pisces have gills covered by an operculum
  - All mammals are viviparous
  - All cyclostomes do not possess jaws and paired fins
  - All reptiles have a three-chambered heart

### Class-Amphibia

1. The pair of Amphibians found in Indian peninsula is [EAMCET 2009]
- Amphyluma and Anguis
  - Tylotriton and Ichthyophis
  - Hyla and Ambystoma
  - Psittacus and Apterix
2. Ovoviviparity is seen in this caecilian [EAMCET 2009]
- Wuchereria
  - Typhlonectus
  - Ichthyophis
  - Uraeotyphlus
3. Select the correct order of classification of Rana tigrina upto genus [Kerala PMT 2008]
- Chordata, craniata, amphibia, gnathostomata, rana
  - Chordata, craniata, gnathostomata, amphibia, rana
  - Chordata, amphibia, gnathostomata, craniata, tigrina
  - Chordata, craniata, amphibia, gnathostomata, tigrina
  - Gnathostomata, craniata, Chordata, rana, tigrina
4. Which one of the following is not a true amphibian animal
- Frog
  - Tortoise
  - Salamander
  - Toad
5. The common name of necturus is
- Cave salamander
  - Congo eel
  - Hell bender
  - Mud puppy
6. Salamander belongs to the class [J & K CET 2002]
- Reptilia
  - Amphibia
  - Aves
  - Mammalia
7. Identify the names of the following animals with their respective classes from the given options [NCERT]



- A – Salamandra, Urochordata; B – Chelone, Cephalochordata; C – Chameleon, Hemichordata
- A – Salamandra, Amphibia; B – Chelone, Amphibia; C – Chameleon, Amphibia
- A – Salamandra, Reptilia; B – Chelone, Reptilia; C – Chameleon, Reptilia
- A – Salamandra, Amphibia; B – Chelone, Reptilia; C – Chameleon, Reptilia

8. *Ichthyophis* belongs to [DPMT 2006]  
 (a) Mammalia (b) Reptilia  
 (c) Amphibia (d) Aves
9. Capacity of amphibians to change colour is called  
 (a) Metachrosis (b) Metachronous  
 (c) Synchronous (d) None of these
10. The name of flying frog is [EAMCET 1998]  
 (a) *Rhacophorus* (b) *Bufo*  
 (c) *Phylllobates* (d) *Necturus*
11. Frog which lives on the trees [NCERT; RPMT 1999]  
 (a) *Alytes* (b) *Bufo*  
 (c) *Hyla* (d) *Rana*
12. The functional kidney of frog tadpole is [CBSE PMT 1995]  
 (a) Pronephros (b) Mesonephros  
 (c) Metanephros (d) Archinephros
13. Axolotl larva of *Ambyostoma* normally fails to metamorphose due to [KCET 1994; AFMC 2006]  
 (a) Lack of Ca and Mg ions in water  
 (b) Absence of phosphorus in water  
 (c) Lack of Iodine in water or diet  
 (d) High concentration of iodine in body
14. Which of the following is a limbless amphibian [NCERT; MP PMT 1993, 2002; Kerala CET 2002; Kerala PMT 2010]  
 (a) Salamander (b) *Ichthyophis*  
 (c) *Amphioxus* (d) *Balanoglossus*
15. Limbless amphibians belong to the order [MHCET 2000; BHU 2001; CPMT 2001]  
 (a) Anura (b) Urodela  
 (c) *Gymnophiona* (d) *Squamata*
16. Which animal is surinam toad [RPMT 2000]  
 (a) *Pipa* (b) *Bufo*  
 (c) *Bombinator* (d) *Alytes*
17. Caecilians belong to the order [JIPMER 1999]  
 (a) *Sirenia* (b) *Squamata*  
 (c) *Neognathae* (d) *Gymnophiona*
18. Fire-bellied toad is  
 (a) *Amphiuma* (b) *Necturus*  
 (c) *Salamandra* (d) *Bombinator*
19. Neoteny is found in [RPMT 1995]  
 (a) Tadpole (b) Salamander  
 (c) *Hyla* (d) Axolotl
20. The skull of frog is [Kerala CET 2005]  
 (a) Tricondylic (b) Monocondylic  
 (c) Dicondylic (d) Noncondylic  
 (e) Polycondylic
21. *Rana tigrina* is the zoological name of [Odisha JEE 2004]  
 (a) Frog (b) Garden lizard  
 (c) Tiger (d) Krait
22. Common Indian bull frog is [NCERT; CBSE PMT 1992; KCET 1998; JIPMER 1999]  
 (a) *Rana tigrina* (b) *Rana esculenta*  
 (c) *Rana silvatica* (d) *Rana cyanophlyctis*
23. Retention of larval characters even after sexual maturity is called [BHU 1993; Kerala CET 2005]  
 (a) Ontogenesis (b) Parthenogenesis  
 (c) Neoteny (d) Phylogenesis
24. Axolotl larva belongs to the order [EAMCET 1994]  
 (a) Urodela (b) Anura  
 (c) Apoda (d) *Stegocephalia*
25. Frog is [NCERT; CPMT 1994]  
 (a) Aminoellic (b) Ammonoellic  
 (c) Ureotelic (d) Uricotelic

### Class-Reptilia


1. Classification of reptilia is based on  
 (a) Scales (b) Type of brain  
 (c) Vacuties (d) None of these
2. Typhlop is a [BHU 2001]  
 (a) True snake (b) False snake  
 (c) True worm (d) Shark
3. Only poisonous lizard of the world is [AMU (Med.) 2006; AFMC 2009]  
 (a) *Draco* (b) *Heloderma*  
 (c) *Sphenodon* (d) *Varanus*
4. Venom of which of the following snakes is proteolytic [AFMC 2012]  
 (a) Viper (b) Krait  
 (c) Cobra (d) Ajar
5. Which of the following is primarily an ectotherm [Odisha JEE 2009]  
 (a) Pigeon (b) Camel  
 (c) Lizard (d) Rabbit
6. Egg of reptiles and birds are [CPMT 2009]  
 (a) Mesolecithal (b) Telolecithal  
 (c) Polylecithal (d) Alecithal
7. Members of class Reptilia are  
 (a) Homoiothermic and amniotic  
 (b) Homoiothermic and anamniotic  
 (c) Poikilothermic and amniotic  
 (d) Poikilothermic and anamniotic
8. Zoological name of common Indian Krait is [Odisha JEE 2005]  
 (a) *Bungarus coeruleus* (b) *Ophiopagus hannah*  
 (c) *Viper russeli* (d) *Naja naja*
9. Carapace is present in [CPMT 1999; BHU 2005]  
 (a) Toad (b) Bird  
 (c) Frog (d) Tortoise
10. Which is a poisonous snake [EAMCET 1998]  
 (a) *Enhydrina* (b) *Typhlops*  
 (c) *Python* (d) *Eryx*
11. The important character of Cobra is [Odisha JEE 1996; BVP 2000]  
 (a) Presence of hood (b) Small scales on head  
 (c) Rounded tail (d) None of these

12. Animals have the innate ability to escape from predation. Examples for the same are given below. Select the incorrect example. [CBSE PMT 2005]  
 (a) Colour change in chameleon  
 (b) Enlargement of body size by swallowing air in puffer fish  
 (c) Poison fangs in snakes  
 (d) Melanism in moths
13. Poison glands of snake are modified [EAMCET 1995; MHCET 2004]  
 (a) Sebaceous glands (b) Ceruminous glands  
 (c) Salivary glands (d) Endocrine glands
14. Snakes receive sound vibrations by [RPMT 1999]  
 (a) Tympanum (b) Body  
 (c) Internal ear (d) Earth
15. To which of the following category dinosaurs belong [HP PMT 2005]  
 (a) Reptiles (b) Amphibians  
 (c) Mammals (d) Birds
16. Whose skin colour does not change [MP PMT 1995]  
 (a) Chameleon (b) Horse  
 (c) Garden lizard (d) Two of the above
17. Which of the following feature is not common between *Newt* & *Hemidactylus* [CPMT 2005, 09]  
 (a) Body is divisible into head, neck, trunk and tail  
 (b) Head with pair of eyes and tympanic membrane  
 (c) Trunk has 2 pairs of limb for locomotion  
 (d) Heart is 3-chambered
18. Which type of respiratory organs are present in spiders and scorpions [AFMC 2006]  
 (a) Book lungs (b) Gills  
 (c) Gill books (d) Lungs
19. Which one of the following is a matching pair of an animal and its one of the characteristics [AIEEE Pharmacy 2004]  
 (a) *Chamaelon* - binocular vision  
 (b) *Heloderma* - poison gland  
 (c) *Varanus* - prehensile tail  
 (d) House lizard - 4 chambered heart
20. Some reptiles show autotomy which means  
 (a) Voluntary breaking tail to confuse enemy  
 (b) Signal for charging  
 (c) Signal for courtship  
 (d) State of starvation prior to death
21. Which among these is not a homoiotherm [Kerala PMT 2012]  
 (a) Aptenodytes (b) Testudo  
 (c) Delphinus (d) Neophron  
 (e) Ornithorhynchus
22. The truly land animals are [J & K CET 2010]  
 (a) Newts (b) Lung-fishes  
 (c) Salamanders (d) *Calotes*
23. The injection of serum of horse which has been repeatedly injected by cobra venom into a person bitten by cobra results in  
 (a) No immunity (b) Natural immunity  
 (c) Active immunity (d) Passive immunity
24. Teeth conducting poison in a snake are called  
 (a) Incisors (b) Canines  
 (c) Heterodont (d) Fangs
25. The reptile which glides in the air is  
 (a) *Draco* (b) *Phrynosoma*  
 (c) *Anguis* (d) *Calotes*
26. Poisonous fangs of a snake are modified  
 (a) Mandible (b) Maxillary teeth  
 (c) Canines (d) Nasals
27. Which of the following is a marine snake  
 (a) *Enhydryna* (b) *Typhlops*  
 (c) *Bungarus* (d) *Naja*
28. Snake moulting consists of  
 (a) Epidermis (b) Dermis  
 (c) Cornified cells (d) Stratum germinativum
29. Pear-shaped head, sharply separated from rest of the body and covered with small scales is a feature of  
 (a) *Pythons* (b) *Vipers*  
 (c) *Kraits* (d) *Cobras*
30. Large size scales fully extended from side to side on the belly are characteristics of  
 (a) Krait and sea snake (b) Cobra and python  
 (c) Rat snake and Cobra (d) Python and Krait
31. Gaviol or gharial is found in [HPMT 1993]  
 (a) Freshwater (b) Sea water  
 (c) Brackish water (d) Terrestrial habitats
32. Name a nonpoisonous snake  
 (a) Cobra (b) Krait  
 (c) Viper (d) Rat snake
33. A stumpy laterally compressed tail is characteristic of  
 (a) Tree snake (b) Sea snake  
 (c) Rat snake (d) Rattle snake
34. Order Squamata consists of [CBSE PMT 1991]  
 (a) Bats (b) Crocodiles  
 (c) Turtles and pangolin (d) Lizards and snakes
35. Which is correct for Indian snakes [MP PMT 1992]  
 (a) Only sea snakes are non-poisonous  
 (b) Only sea snakes are poisonous  
 (c) All water snakes are poisonous  
 (d) All sea snakes are poisonous
36. Besides mammals, diaphragm also occurs in [JKCME 1992]  
 (a) Birds (b) Crocodiles  
 (c) Fishes (d) Toads
37. The vestiges of girdles are found in [AMU (Med.) 2010]  
 (a) Cobra (b) Krait  
 (c) Rattle snake (d) Python
38. In suborder ophidia, the vertebrae are [EAMCET 1998; BHU 1999]  
 (a) Amphicoelus (b) Acoelus  
 (c) Heterocoelus (d) Procoelus
39. Gila Monster *Heloderma* occurs in [MP PMT 2004]  
 (a) Africa (b) America  
 (c) Central Asia (d) China

40. When the tail is cylindrical and ventral scales do not extend the entire width of the belly, the snake is [BHU 1994]  
(a) Non-poisonous  
(b) Either poisonous or non-poisonous  
(c) Definitely poisonous  
(d) Deadly poisonous
41. Cleidoic eggs are found in [BHU 1994]  
(a) Fishes (b) Amphibia  
(c) Reptiles (d) None of these
42. Even ventricles of reptiles are partitioned but there is mixing of blood [AIIMS 1996]  
(a) Due to common ejection and entrance of blood in lungs  
(b) Auricles are non-partitioned  
(c) Heart is partially four-chambered  
(d) None of these
43. *Calotes versicolor* is a [Odisha JEE 1997]  
(a) House lizard (b) Garden lizard  
(c) Flying lizard (d) Rock lizard
44. Animal which can move the upper jaw [Kerala PMT 1997]  
(a) Elephant (b) Crocodile  
(c) Clarius (d) Frog
45. Foramen of Panizzae is found in the heart of [BVP 2003]  
(a) Rabbit (b) Crocodile  
(c) Pigeon (d) Frog
46. *Typhlops* is [BHU 2001]  
(a) Sea snake (b) Grass snake  
(c) Glass snake (d) Blind snake
47. The snake having head shield and elongated hexagonal vertebrals is [EAMCET 2000]  
(a) *Naja* (b) *Eryx*  
(c) *Bungarus* (d) *Ptyas*
48. Which of the following is a poisonous snake [CBSE PMT 2000]  
(a) *Eryx* (b) *Natrix*  
(c) Tree snake (d) Russel's viper
49. Which of the following snake has hind legs [CPMT 2000]  
(a) Python (b) *Bungarus*  
(c) *Typhlops* (d) King cobra
50. The reptile which lacks penis belongs to [EAMCET 2000]  
(a) Ophidia (b) Crocodilia  
(c) Gymnophiona (d) Rhynchocephalia
51. Snake has [MHCET 2000; Pb. PMT 2004]  
(a) Movable eyelids (b) No eyelids  
(c) Immovable eyelids (d) Eyelids placed in pouches
52. Most favourable land adaptation for reptile is [CBSE PMT 2001]  
(a) Moist skin (b) Scales on body  
(c) Pulmonary respiration (d) None of these
53. Post anal tail is present in [CBSE PMT 2001]  
(a) Cobra (b) Earth worm  
(c) Scorpion (d) Lower invertebrate
54. Diapside skull is found in the following [MP PMT 2001]  
(a) *Natrix*, *Draco* and Turtle  
(b) Crocodile, Turtle and *Seymouria*  
(c) *Sphenodon*, Crocodile and Viper  
(d) *Calotes*, Cobra and *Varanosaurus*
55. Antivenin injections used for snake bite are prepared at [BCECE 2001]  
(a) IVRI, Bareilly  
(b) NDRI, Karnal  
(c) Haffkin's Research Institute, Mumbai  
(d) IARI, New Delhi
56. Which of the following systems in man is affected by the bite of cobra [AFMC 2001]  
(a) Digestive (b) Nervous  
(c) Excretory (d) Circulatory
57. Turtles are [KCET 2002; J & K CET 2012]  
(a) Pisces (b) Reptiles  
(c) Molluscs (d) Arthropods
58. The type of dentition in Crocodile is [MP PMT 2002]  
(a) Acrodont (b) Bunodont  
(c) Pleurodont (d) Thecodont
59. Scientific name of king cobra is [Odisha JEE 2002]  
(a) *Naja naja* (b) *Bungarus coeruleus*  
(c) *Naja hannah* (d) *Vipera russelli*
60. Which of the following is incorrectly matched [Odisha JEE 2010]  
(a) Spiny tailed lizard - *Hardwickia*  
(b) Garden lizard - *Hemidactylus flaviviridis*  
(c) Gila monster - *Heloderma*  
(d) Monitor lizard - *Varanus*
61. The characteristics of class Reptilia are [NCERT; NEET (Karnataka) 2013]  
(a) Body covered with moist skin which is devoid of scales, the ear is represented by a tympanum, alimentary canal, urinary and reproductive tracts open into a common cloaca  
(b) Fresh water animals with bony endoskeleton, air-bladder to regulate buoyancy  
(c) Marine animals with cartilaginous endoskeleton, body covered with placoid scales  
(d) Body covered with dry and cornified skin, scales over the body are epidermal, they do not have external ears

### Class-Aves

1. Characteristic features such as four-chambered heart, feather and pneumatic bone is applicable to the class of vertebrate [NCERT; Odisha JEE 2002]  
(a) Cyclostomata (b) Aves  
(c) Reptilia (d) Mammals
2. Quill feathers at the base of quill wings are called [BHU 1999]  
(a) Remiges (b) Barbules  
(c) Coverts (d) Down feathers
3. The pelvic girdle of birds is attached to a complex structure formed by the fusion of last thoracic, all lumbar and first five caudal vertebra. This structure is called [MP PMT 1993; AFMC 2005]  
(a) Synsacrum (b) Symphysis  
(c) Synkaryon (d) Sympelvis
4. Penguin is found in [CBSE PMT 1990; BHU 1997]  
(a) Africa (b) Australia  
(c) America (d) Antarctica

5. Flightless bird, cassowary is found in [CBSE PMT 1996]  
(a) Australia (b) Newzealand  
(c) Indonesia (d) Mauritious
6. Which animals have a beak with jaws but no teeth [CPMT 1995]  
(a) Aves (b) Snakes  
(c) Mammals (d) All the above
7. Characteristic feature of aves is [CPMT 1995]  
(a) Presence of beak and feathers  
(b) Ability to lay eggs  
(c) Air spaces in lungs  
(d) All the above
8. Which of the following group of animals maintain high and constant body temperature such as mammals [AFMC 2005]  
(a) Reptiles (b) Amphibians  
(c) Birds (d) Fishes
9. Only right aortic arches are present in [Manipal 2005]  
(a) Reptilia (b) Mammals  
(c) Birds (d) None of these
10. Only one ovary is present in the  
(a) Aquatic reptiles (b) Terrestrial reptiles  
(c) Birds (d) Egg laying mammals
11. Flightless birds belong to [CBSE PMT 2002]  
(a) Ratitae (b) Neornithes  
(c) Archaeornithes (d) None of these
12. Cleidoic egg is an adaptation for [RPMT 2001]  
(a) Aerial life (b) Marine life  
(c) Aquatic life (d) Terrestrial life
13. Pneumatic bones of birds  
(a) Increase the respiratory rate  
(b) Increase the heart beat rate  
(c) Increase the CO<sub>2</sub> output  
(d) Increase the buoyancy
14. Which one is characteristic for birds [NCERT; Wardha 2005]  
(a) They are flying animals  
(b) They are warm blooded  
(c) They are Bipedal and have feathers  
(d) They are quadruped and have scales
15. The beak in birds is toothed in [MP PMT 1993]  
(a) Ostrich (b) Kiwi  
(c) Archaeopteryx (d) Pelican
16. Pneumatic bones are found in [CBSE PMT 1996; AFMC 2000, 02]  
(a) Domestic lizard (b) Tadpole of frog  
(c) Flying lizard (d) Pigeon
17. The vertebrae of birds are characteristically [AIIMS 1999]  
(a) Heterocoelous (b) Acoelous  
(c) Opisthocoelous (d) Amphicoelous
18. See the following animals and identify them [NCERT]
- 
- (a) Calotes, Psittacula (b) Testudo, Pavo  
(c) Pavo, Psittacula (d) Psittacula, Pavo
19. The special sound producing organ in birds is [BVP 2001]  
(a) Syrinx (b) Glottis  
(c) Larynx (d) Oesophaagus
20. Who called birds are glorified reptiles [BVP 2001]  
(a) Huxley (b) Romer  
(c) Mendel (d) Robert Hooke
21. Which is not aerial adaptation of Birds [RPMT 2001]  
(a) Single ovary (b) Pneumatic bone  
(c) Gizzard (d) Keeled sternum
22. Renal portal system is absent in [BHU 1998, 2008]  
(a) Amphibians (b) Reptiles  
(c) Amphibians and reptiles (d) Birds
23. Which one of the following is a flightless bird [AIIMS 2001; MHCET 2003; J & K CET 2010]  
(a) Passer (b) Corvus  
(c) Aptenodytes (d) Pavo cristatus
24. The presence of feathers and power of flight are characteristic feature of [NCERT; BVP 2000]  
(a) Aves (b) Reptilia  
(c) Mammals (d) Amphibians
25. Birds are [AIIMS 2000]  
(a) Cold blooded (b) Homoeothermal  
(c) Poikilothermal (d) Homeopoesis
26. Kingfisher is a bird in which the feet are  
(a) Scratching type (b) Raptorial type  
(c) Perching type (d) Wading type
27. Both male and female pigeons secrete milk through  
(a) Mammary glands (b) Crop glands  
(c) Salivary glands (d) Gizzard glands
28. Birds differ from bats in the absence of  
(a) 4-chambered heart (b) Homoeothermy  
(c) Diaphragm (d) Tracheae
29. The wishbone of the birds is derived from  
(a) Skull (b) Pectoral girdle  
(c) Pelvic girdle (d) Hindlimb
30. Birds have bipedal locomotion as it [NCERT]  
(a) Reduces body weight  
(b) Increases rate of locomotion  
(c) Provides more support to the body  
(d) Spares forelimbs for flight
31. The largest egg belongs to [CPMT 1994; MHCET 2000]  
(a) Elephant (b) Whale  
(c) Dinosaur (d) Ostrich
32. Bone marrow does not occur in [BHU 1994]  
(a) Fishes (b) Amphibians  
(c) Birds (d) Reptiles
33. Preen gland occurs in [RPMT 1995]  
(a) Pisces (b) Aves  
(c) Reptilia (d) Mammalia
34. Without exception, all birds are [CPMT 1995]  
(a) Omnivorous  
(b) Have feathers and fly  
(c) Forms nests and care them  
(d) Have calcareous shelled egg



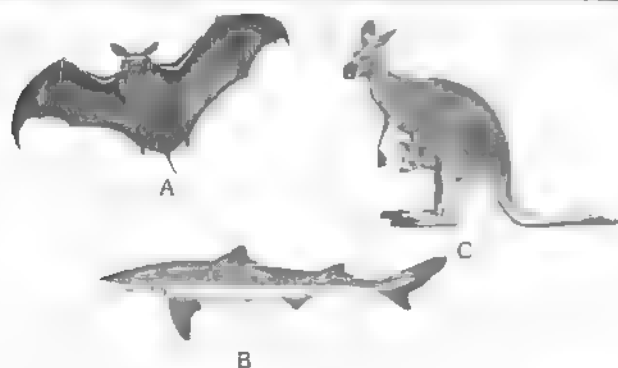
35. Which of the following is merrythought bone [EAMCET 1995]  
 (a) Coracoid (b) Clavicle  
 (c) Scapula (d) Suprascapula
36. The living wingless or flightless birds belong to the superorder [EAMCET 1995]  
 (a) Palaeognathae (b) Odontognathae  
 (c) Archaeornithes (d) None of these
37. Kiwi is found in [CPMT 1996]  
 (a) India (b) South America  
 (c) New Zealand (d) East Indies
38. Uropygial gland is associated with [MP PMT 2013]  
 (a) Lizard (b) Shark  
 (c) Frog (d) Pigeon
39. Flight muscles of bird are attached to [Kerala PMT 2001]  
 (a) Clavicle (b) Coracoid  
 (c) Keel of sternum (d) Scapula

### Class-Mammalia

1. Instead of tooth, balven (hanging horny plates in mouth) are found in [Odisha JEE 2008]  
 (a) Blue whale (b) Shark  
 (c) Dolphin (d) *Archaeopteryx*
2. An egg laying mammal is [NCERT; J & K CET 2008]  
 (a) Didelphys (b) Macaca  
 (c) Ornithorhynchus (d) Macropus
3. Which one of the following animals is correctly matched with its one characteristic and the taxon [AIIMS 2008; NEET (Karnataka) 2013]
- |     | Animals             | Characteristic           | Taxon     |
|-----|---------------------|--------------------------|-----------|
| (a) | Millipede           | Ventral nerve cord       | Arachnida |
| (b) | Duckbilled platypus | Oviparous                | Mammalian |
| (c) | Silver fish         | Pectoral and pelvic fins | Chordate  |
| (d) | Sea anemone         | Triploblastic            | Cnidaria  |
4. Egg-laying mammals are grouped as [Pune CET 1998]  
 (a) Eutheria (b) Prototheria  
 (c) Rodentia (d) Metatheria
5. Which pair of characters are found without exception in all mammals [RPMT 2001]  
 (a) Hair and viviparity  
 (b) Viviparity and mammary glands  
 (c) Viviparity and internal fertilization  
 (d) Mammary glands and internal fertilization
6. Which of the following animals is an example of class mammalia [MP PMT 1998]  
 (a) *Manis* (b) *Planorbis*  
 (c) *Hydrophis* (d) *Psittacula*
7. External ears are characteristics of [NCERT; MP PMT 1994, 97]  
 (a) Birds (b) Mammals  
 (c) Birds and mammals (d) Mammals and reptiles
8. Eutherian mammals are [MP PMT 1996; BVP 2002]  
 (a) Oviparous  
 (b) Viviparous  
 (c) Ovoviviparous  
 (d) Both oviparous and ovoviviparous
9. Which one of the following is not a mammalian character [Kerala PMT 2010]  
 (a) Presence of milk producing glands  
 (b) They have two pairs of limbs  
 (c) Skin is unique in possessing hair  
 (d) Presence of external ears called pinnae  
 (e) Homodont type of dentition
10. Which one of the following mammals is not an odd-toed ungulate [DUMET 2009]  
 (a) Rhinoceros (b) Camel  
 (c) Zebra (d) Horse
11. Animals belonging to the order 'rodentia' have  
 (a) Long incisors (b) long canines  
 (c) short incisors (d) long molars
12. *Tachyglossus* is a connecting link between [DUMET 2009]  
 (a) Reptiles and birds (b) Amphibians and reptiles  
 (c) Birds and mammals (d) Reptiles and mammals
13. Why do mammals lack mucus glands in their skin [AIIMS 1993]  
 (a) The skin is not slippery  
 (b) The skin is tough  
 (c) The epidermis has many layers of cells  
 (d) The skin is not respiratory
14. In which one of the following sets of animals do all the four give birth to young ones [NCERT; CBSE PMT 2006; KCET 2009]  
 (a) Shrew, Bat, Cat, Kiwi  
 (b) Kangaroo, Hedgehog, Dolphin, Loris  
 (c) Lion, Bat, Whale, Ostrich  
 (d) Platypus, Penguin, Bat, Hippopotamus
15. Which of the following is a connecting link between mammals and reptiles [AFMC 2009]  
 (a) *Peripatus* (b) *Balanoglossus*  
 (c) *Ornithorhynchus* (d) *Archaeopteryx*
16. 12 pairs of cranial nerves are present in [AIIMS 1993]  
 (a) Reptilia (b) Birds only  
 (c) Mammals only (d) All the above
17. Rabbit belongs to the order [CBSE PMT 1991]  
 (a) Rodentia (b) Lagomorpha  
 (c) Artiodactyla (d) Perissodactyla
18. Mammals have originated from which of the following [WB JEE 2012]  
 (a) Pisces (b) Amphibia  
 (c) Reptilia (d) Aves
19. Which one of the following is a metatherian  
 (a) Didelphis (b) Ornithorhynchus  
 (c) Tarsier (d) Hystericus

20. The mammal which possesses both the reptiles and mammalian characters [DPMT 1993]  
(a) Marsupials (b) Monotremes  
(c) Equus (d) *Oryctolagus*
21. Kangaroo is a member of which order [RPMT 1995; MP PMT 2000]  
(a) Monotremata (b) Marsupilia  
(c) Prototheria (d) Insectivora
22. Bat can travel with [AFMC 1997]  
(a) Eyes open  
(b) Eyes plugged and ears open  
(c) Ears plugged and eyes open  
(d) Ears closed and eyes plugged
23. Egg laying mammals are found in  
(a) India (b) South Africa  
(c) Africa (d) Australia
24. A fat called blubber could be obtained from [Kerala PMT 2001]  
(a) Bat (b) Dolphin  
(c) Shark (d) Blue whale
25. Identify the aquatic mammal(s) from the following  
(A) *Balaenoptera* (B) *Equus*  
(C) *Delphinus* (D) *Pterophus*  
(E) *Felis* [Kerala PMT 2010]  
(a) (A) and (C) only (b) (B) and (D) only  
(c) (E) only (d) (D) and (E) only  
(e) (B) and (E) only
26. Which of the following four animals does not come under the same order as the other three [BHU 2012]  
(a) Rat (b) Squirrel  
(c) Porcupine (d) Rabbit
27. Ruminants belongs to order [Manipal 2005]  
(a) Proboscida (b) Artiodactyla  
(c) Marsupials (d) Edentata
28. Pouch is seen in [J & K CET 2010]  
(a) Platypus (b) Bat  
(c) Lemur (d) Marsupial
29. The biological name of 'domestic cat' is [MP PMT 1993]  
(a) *Panthera domestica* (b) *Felis domestica*  
(c) *Felis leo* (d) *Panthera indica*
30. Which one of the following characters is not typical of the class Mammalia [CBSE PMT 2005]  
(a) Thecodont dentition (b) Alveolar lungs  
(c) Ten pairs of cranial nerves (d) Seven cervical vertebrae
31. Which of the following structures is present characteristically only in mammalian brain [MP PMT 2004]  
(a) Corpus fibrosum (b) Corpus striatum  
(c) Corpus luteum (d) Corpus callosum
32. Flippers of seal are modified [AFMC 2004]  
(a) Fins (b) Hind limb  
(c) Forelimb (d) Gills
33. The feet with two toes forming cloven hoof is seen in [Kerala PMT 2004]  
(a) Horse (b) Zebra  
(c) Rhinoceros (d) Elephant  
(e) Sheep
34. The zoological name of common hare found in northern India is [MP PMT 2001; CPMT 2004]  
(a) *Oryctolagus cuniculus* (b) *Lepus ruficaudatus*  
(c) *Dasyus sexcinctus* (d) *Alactaga indica*
35. The following mammal lays eggs [KCET 1998; J & K CET 2005]  
(a) Porcupine (b) Platypus  
(c) Kangaroo (d) Koala
36. Double Vagina are found in [RPMT 1999]  
(a) Monotremata (b) Eutheria  
(c) Marsupials (d) All of the above
37. Which of the following is not viviparous [HP PMT 2005; AIPMT (Cancelled) 2015]  
(a) Mole (b) Platypus  
(c) Kangaroo (d) Shrew
38. One of the following is a very unique feature of the mammalian body [BHU 2000; RPMT 2002; CBSE PMT 2004; KCET 2006; MP PMT 2012]  
(a) Four chambered heart (b) Rib cage  
(c) Homeothermy (d) Presence of diaphragm
39. Select the correct set of animals of class-mammalia [Odisha PMT 2002]  
(a) Lion, hippopotamus, penguin, bat  
(b) Lion, bat, whale, ostrich  
(c) Hippopotamus, penguin, whale, kangaroo  
(d) Whale, bat, kangaroo, hippopotamus
40. Which character is not same in aves and mammals [RPMT 2002]  
(a) Single systemic arch (b) Metanephric kidney  
(c) Seven cervical vertebrae (d) Homoiotherms
41. All mammals [NCERT; AMU (Med.) 2002; Odisha JEE 2009]  
(a) Give birth to live young  
(b) Have a thick coat of hair  
(c) Nourish their young with milk  
(d) Have a uterus
42. Most animals domesticated by man belong to the order [BHU 2002]  
(a) Carnivora (b) Rodentia  
(c) Ungulata (d) Lagomorpha
43. Which of the following is prototherian [BHU 1999]  
(a) Platypus (b) Macropus  
(c) Opposum (d) Bradypus
44. Jaw suspension characteristic of mammals is [MP PMT 2002]  
(a) Amphistylic (b) Cranioistylic  
(c) Autodiastylic (d) Hyostylic
45. When embryo develops in the body of female but it does not obtain nutrients from the mother [RPMT 1999]  
(a) Ovo-viviparous (b) Viviparous  
(c) Oviparous (d) None of these

46.



Identify the names of animals A, B and C

[NCERT]

- (a) *Balaenopter*, *Macropus*, *Pteropus*
- (b) *Balaenoptera*, *Pteropus*, *Macropus*
- (c) *Macropus*, *Balaenoptera*, *Pteropus*
- (d) *Pteropus*, *Balaenoptera*, *Macropus*

47. Which of the following is rightly matched

[CPMT 1995]

- (a) Mammalia-Human beings
- (b) Mollusca - Centipede
- (c) Pisces - Silver fish
- (d) Echinoderm - Echidna

48. Consider the following four statements (A-D) about certain desert animals such as kangaroo rat

- (A) They have dark colour and high rate of reproduction and excrete solid urine
- (B) They do not drink water, breathe at a slow rate to conserve water and have their body covered with thick hairs
- (C) They feed on dry seeds and do not require drinking water
- (D) They excrete very concentrated urine and do not use water to regulate body temperature.

Which two of the above statements for such animals are true  
Options

[CBSE PMT 2008]

- (a) C and A
- (b) C and D
- (c) A and B
- (d) B and C

49. Considered the following four conditions (A - D) and select the correct pair of them as adaptation to environment in desert lizards

The conditions

- (A) Burrowing in soil to escape high temperature
- (B) Losing heat rapidly from the body during high temperature
- (C) Bask in sun when temperature is low
- (D) Insulating body due to thick fatty dermis

Options

[CBSE PMT (Pre.) 2011]

- (a) (A), (B)
- (b) (C), (D)
- (c) (A), (C)
- (d) (B), (D)

50. Which one of the following is categorised as a parasite in true sense

[CBSE PMT (Pre.) 2011]

- (a) The cuckoo (Koel) lays its egg in crow's nest
- (b) The female *Anopheles* bites and sucks blood from humans
- (c) Human foetus developing inside the uterus draws nourishment from the mother
- (d) Head louse living on the human scalp as well as laying eggs on human hair

51. Which one of the following animals is correctly matched with its particular named taxonomic category

[NCERT; CBSE PMT (Pre.) 2011]

- (a) Housefly - *Musca*, an order
- (b) Tiger - *Tigris*, the species
- (c) Cuttlefish - *Mollusca*, a class
- (d) Humans - *Primata*, the family

52. Pick the mammal with true placenta

[KCET 2011]

- (a) Kangaroo
- (b) *Echidna*
- (c) Platypus
- (d) Mongoose

53. Which of the following is not a mammalian character

[MHCET 2002]

- (a) Hairy skin
- (b) Muscular diaphragm
- (c) 3-chamberd heart
- (d) RBCs enucleated

54. Diaphragm is found in

[MH CET 2001]

- (a) Crocodile
- (b) Kangaroo
- (c) Ostrich
- (d) Snake

55. Arboreal mammals have

[MH CET 2001]

- (a) Flying character
- (b) Burrowing character
- (c) Climbing character
- (d) None of the above

56. Hairs occur in all mammals except those of

- (a) Chiroptera
- (b) Rodentia
- (c) Cetacea
- (d) Primates

57. The sweat gland are scanty in

- (a) Elephant
- (b) Man
- (c) Rabbit
- (d) Polar bear

58. "Sea lion" belongs to

- (a) Class Reptilia
- (b) Subclass Prototheria
- (c) Superclass Pisces
- (d) Order Carnivora

59. The Zoological name of 'Lion-tailed macaque' is

- (a) *Macaca rhesus*
- (b) *Macaca silenus*
- (c) *Macaca mulatta*
- (d) None of these

60. Locomotion in Kangaroo is

- (a) Saltatorial
- (b) Volant
- (c) Cursorial
- (d) Creeping

61. Pinna is absent in

[EAMCET 1994]

- (a) Sirenia
- (b) Primates
- (c) Rodentia
- (d) All of these

62. Which one has a poison gland

[RPMT 1995]

- (a) Wall lizard
- (b) *Scollodon*
- (c) Rat snake
- (d) Male platypus

63. In mammals, few vertebrae join to form

[EAMCET 1995]

- (a) Humerus
- (b) Femur
- (c) Synsacrum
- (d) Atlas

64. Whale is air breather but can live under water for a long time because it possesses

[CPMT 1997]

- (a) Large lungs
- (b) Small lungs
- (c) Blubber
- (d) Retea mirabile

65. Only poisonous mammal or monotreme mammal is

[CBSE PMT 1992, 93; RPMT 1995; CPMT 1997; BCECE 1997; MP PMT 2002; WB JEE 2009]

- (a) *Ornithorhynchus*
- (b) *Echidna*
- (c) Guinea pig
- (d) Snake

66. Which will not affect echolocation in bats

[AFMC 1997]

- (a) Covering eyes only
- (b) Covering the whole head
- (c) Covering the ears
- (d) Covering the eyes and ears

67. Most primitive living mammals which provide an evidence of organic evolution from geographical distribution are found in [AIIMS 1998]  
 (a) Africa (b) Australia  
 (c) China (d) India
68. The zoological name of lion is [MP PMT 2000]  
 (a) *Felis leo* (b) *Panthera tigris*  
 (c) *Panthera pardus* (d) *Panthera leo persica*
69. Which of the following mammals lacks corpus callosum [MP PMT 2000]  
 (a) *Macaca* (b) *Macropus*  
 (c) *Balaenoptera* (d) *Ornithorhynchus*
70. Vestigial pelvic girdle and bones of hind limbs are characteristic of [HPMT 2000]  
 (a) Whales (b) Otters  
 (c) Rodents (d) Sharks
71. Which of the following exist in maximum number of terms of genera and species [AFMC 2000]  
 (a) Aquatic mammals (b) Carnivore mammals  
 (c) Herbivore mammals (d) Terrestrial mammals
72. Which of the following is largest mammals [MHCET 2000]  
 (a) Whale (b) Elephant  
 (c) Camel (d) Dinosaur
73. Without teats, mammary glands are found in [EAMCET 1998; BHU 2000; MHCET 2000; CBSE PMT 2001]  
 (a) Prototheria (b) Metatheria  
 (c) Eutheria (d) Theria
74. Bats belong to which order [MP PMT 1994; CBSE PMT 2000; BVP 2001]  
 (a) Carnivora (b) Chiroptera  
 (c) Dermoptera (d) Cetacea
75. A group of animals having marsupium [MP PMT 2001; CBSE PMT 2001; MHCET 2001; BVP 2001]  
 (a) Monotremata (b) Eutheria  
 (c) Metatheria (d) Prototheria
76. Echidna is found in [BHU 2001]  
 (a) India (b) Africa  
 (c) Malaysia (d) Australia
77. Which one of the following is egg-laying mammal [RPMT 2001; MP PMT 2001]  
 (a) Pangolin (b) *Tachyglossus*  
 (c) Porcupine (d) Bat
78. Order primata contains [CPMT 2001]  
 (a) Shrew and hedge hog (b) Bats and vampire  
 (c) Monkeys and man (d) Horses and zebra
79. The order insectivora comes under [KCET 2001]  
 (a) Class-mammalia (b) Class-insecta  
 (c) Phylum-echinodermata (d) Phylum-arthropoda
80. Which of the following represents order of 'Horse' [NEET 2017]  
 (a) *Equidae* (b) *Perissodactyla*  
 (c) *Caballus* (d) *Ferus*
2. Given below are types of cells present in some animals. Each one is specialized to perform a single specific function except [NCERT]  
 (a) Choanocytes (b) Interstitial cells  
 (c) Gastrodermal cells (d) Nematocytes
3. Which one of the following sets of animals share a four chambered heart [NCERT]  
 (a) Amphibian, Reptiles, Birds  
 (b) Crocodiles, Birds, Mammals  
 (c) Crocodiles, Lizards, Turtles  
 (d) Lizards, Mammals, Birds
4. Which of the following pairs of animals has non glandular skin [NCERT]  
 (a) Snake and Frog (b) Chameleon and Turtle  
 (c) Frog and Pigeon (d) Crocodile and Tiger
5. Birds and mammals share one of the following characteristics as a common feature [NCERT]  
 (a) Pigmented skin  
 (b) Allimentary canal with some modification  
 (c) Viviparity  
 (d) Warm blooded nature
6. Which one of the following sets of animals belong to a single taxonomic group (order) [NCERT; AFMC 2012]  
 (a) Cuttlefish, Jellyfish, Silverfish, Dogfish, Starfish  
 (b) Bat, Pigeon, Butterfly  
 (c) Monkey, Chimpanzee, Man, Gorilla  
 (d) Silkworm, Tapeworm, Earthworm
7. Which one of the following statements is incorrect [NCERT]  
 (a) Mesoglea is present in between ectoderm and endoderm in *Obelia*  
 (b) Radial symmetry is found in *Asterias*  
 (c) *Fasciola* is a pseudocoelomate animal  
 (d) *Taenia* is a triploblastic animal
8. Which one of the following statements is incorrect [NCERT]  
 (a) In cockroaches and prawns excretion of waste material occurs through malpighian tubules.  
 (b) In ctenophors, locomotion is mediated by comb plates  
 (c) In *Fasciola* flame cells take part in excretion  
 (d) Earthworms are hermaphrodites and yet cross fertilization take place among them
9. Which one of the following is oviparous [NCERT]  
 (a) Platypus (b) Flying fox (Bat)  
 (c) Elephant (d) Whale
10. Which one of the following is not a poisonous snake [NCERT]  
 (a) Cobra (b) Viper  
 (c) Python (d) Krait

# NCERT

## Exemplar Questions

1. In some animal groups, the body is found divided into compartments with at least some organs/organ repeated. This characteristic feature is named [NCERT]  
 (a) Segmentation (b) Metamerism  
 (c) Metagenesis (d) Metamorphosis

11. Match the following list of animals with their level of organization

Division of Labour

Division of Labour	Animal
A. Organ level	i. <i>Pheritima</i>
B. Cellular aggregate level	ii. <i>Fasciola</i>
C. Tissue level	iii. <i>Spongilla</i>
D. Organ system level	iv. <i>Obelia</i>

Choose the correct match showing division of labour with animal example [NCERT]

- (a) i-B, ii-C, iii-D, iv-A  
(b) i-B, ii-D, iii-C, iv-A  
(c) i-D, ii-A, iii-B, iv-C  
(d) i-A, ii-D, iii-C, iv-B
12. Body cavity is the cavity present between body wall and gut wall. In some animals the body cavity is not lined by mesoderm. Such animals are called [NCERT]

- (a) Acoelomate (b) Pseudocoelomate  
(c) Coelomate (d) Haemocoelomate

13. Match the column A with column B and choose the correct option

Column A

- A. Porifera  
B. Aschelminthes  
C. Annelida

Column B

- i. Canal system  
ii. Water-vascular system  
iii. Muscular Pharynx Comb Plates  
iv. Jointed appendages  
v. Metameres

- (a) A-ii, B-iii, C-v, D-iv, E-i  
(b) A-ii, B-v, C-iii, D-iv, E-i  
(c) A-i, B-iii, C-v, D-iv, E-ii  
(d) A-i, B-v, C-iii, D-iv, E-ii

[NCERT]



## Critical Thinking

### Objective Questions

1. Note the following :

- A. It is a fresh water, metamerically segmented protostome  
B. The clitellum is absent  
C. It is unisexual  
D. Its larval form is Trochophore  
E. The nervous system is found in the epidermis  
Which of the above is true of "paddle worm"

[EAMCET 2009]

- (a) A, B and E (b) B, C and E  
(c) B, C and D (d) C, D and E

2. Which of the following endoparasites of humans does show viviparity [AIPMT (Cancelled) 2015]

- (a) *Enterobius vermicularis* (b) *Trichinella spiralis*  
(c) *Ascaris lumbricoides* (d) *Ancylostoma duodenale*

3. Match the following

List-I		List-II	
(A)	Green glands	(I)	Scolopendra
(B)	Amphids and phasmids	(II)	Respiratory organ
(C)	Ctenidia	(III)	Shell protein
(D)	Poison claw	(IV)	Excretory organs
(E)	Concholin	(V)	Sense organs

The correct match is

[EAMCET 2009]

- |     |     |     |    |     |     |
|-----|-----|-----|----|-----|-----|
|     | A   | B   | C  | D   | E   |
| (a) | IV  | V   | II | I   | III |
| (b) | I   | III | IV | V   | II  |
| (c) | II  | IV  | V  | III | I   |
| (d) | III | IV  | V  | I   | I   |

4. Match list I with list II and choose the correction option

List I (Organism)

List II (Excretory structure)

- |                          |                        |
|--------------------------|------------------------|
| (A) Cockroach            | (1) Nephridia          |
| (B) <i>Clarias</i>       | (2) Malpighian tubules |
| (C) Earthworm            | (3) Kidneys            |
| (D) <i>Balanoglossus</i> | (4) Flame cells        |
| (E) Flatworm             | (5) Proboscis gland    |

[Kerala PMT 2009]

- (a) (A) — (1), (B) — (3), (C) — (2), (D) — (4), (E) — (5)  
(b) (A) — (3), (B) — (1), (C) — (2), (D) — (5), (E) — (4)  
(c) (A) — (2), (B) — (1), (C) — (3), (D) — (5), (E) — (4)  
(d) (A) — (2), (B) — (1), (C) — (5), (D) — (3), (E) — (4)  
(e) (A) — (2), (B) — (3), (C) — (1), (D) — (5), (E) — (4)

5. Coelom is cavity found between

[JIPMER 2000]

- (a) Ectoderm and Endoderm  
(b) Mesoderm and Endoderm  
(c) Body wall and ectoderm  
(d) Mesoderm and body wall

6. In *Hydra*, both pseudopodia and flagella occur in

- (a) Nutritive cells (b) Epithelio-muscular cells  
(c) Sensory cells (d) Gland cells

7. Common between trichocysts of *Paramecium* and nematocysts of *Hydra* is [CPMT 1994]

- (a) Attachment and defence (b) Defence only  
(c) Sensitivity (d) Food capturing

8. In *Hydra*, egestion of undigested food and excretion of nitrogenous wastes occur through [CBSE PMT 2001]

- (a) Mouth and tentacles (b) Mouth and body wall  
(c) Mouth and mouth (d) Body wall and body wall

9. The scientific name of Asian tiger mosquito [WB JEE 2009]

- (a) *Aedes aegypti* (b) *Aedes albopictus*  
(c) *Aedes taeniorhynchus* (d) *Aedes albolineatus*

10. *Taenia saginata* differs from *Taenia solium* in [CBSE PMT 1990]  
 (a) Absence of scolex hooks  
 (b) Absence of scolex hooks and uterine branching  
 (c) Absence of scolex hooks and presence of both male and female reproductive organs  
 (d) Presence of scolex hooks
11. Correctly matched set of phylum, class and example is [MP PMT 2009]  
 (a) Protozoa – Mastigophora – Entamoeba  
 (b) Mollusca – Bivalvia – Pinactoda  
 (c) Arthropoda – Diplopoda – Scolopendra  
 (d) Chordata – Cyclostomata – Phrynosoma
12. Sites of first, second and third moulting of *Ascaris* larva are [AIIMS 2002]  
 (a) Soil, lung, intestine (b) Soil, alveoli, lung  
 (c) Soil, Intestine, lung (d) Liver, stomach, intestine
13. Match List I with List II and select the correct option [Kerala PMT 2008]
- | List I |               | List II |            |
|--------|---------------|---------|------------|
| A.     | Protozoa      | 1.      | Pennatula  |
| B.     | Aschelminthes | 2.      | Beroe      |
| C.     | Porifera      | 3.      | Monocystis |
| D.     | Ctenophora    | 4.      | Wuchereria |
| E.     | Cnidaria      | 5.      | Cliona     |
- (a) A-3, B-5, C-4, D-1, E-2  
 (b) A-4, B-3, C-5, D-2, E-1  
 (c) A-3, B-4, C-5, D-2, E-1  
 (d) A-2, B-4, C-5, D-3, E-1  
 (e) A-3, B-4, C-5, D-1, E-2
14. Dorsal vessel of Earthworm is [APMEE 1996; Pb. PMT 1999]  
 (a) Distribution  
 (b) Collecting  
 (c) Collecting in first thirteen segments and distributing in the rest  
 (d) Distributing in first thirteen segments and collecting in the rest
15. Blood glands of *Pheretima* take part in [APMEE 2001]  
 (a) Formation of red blood corpuscles  
 (b) Formation of phagocytes  
 (c) Maintenance of blood volume  
 (d) Maintenance of blood circulation
16. Read the following statements and select the correct option [NCERT; Kerala PMT 2012]  
 A. Circulatory system in arthropods is of closed type  
 B. Parapodia in annelids help in swimming  
 C. Phylum Mollusca is the second largest animal phylum  
 D. Aschelminthes are dioecious  
 (a) A and C alone are wrong  
 (b) A alone is wrong  
 (c) C alone is wrong  
 (d) C and D alone are wrong  
 (e) D alone is wrong
17. Weberian ossicles are found in [AIIMS 1999]  
 (a) Frogs (b) Snakes  
 (c) Fishes (d) Birds
18. Match the items in column I with column II and choose the correct option [Kerala PMT 2009]
- | Column I |               | Column II |             |
|----------|---------------|-----------|-------------|
| (A)      | Ascus         | (1)       | Spirulina   |
| (B)      | Basidium      | (2)       | Penicillium |
| (C)      | Protista      | (3)       | Agaricus    |
| (D)      | Cyanobacteria | (4)       | Euglena     |
| (E)      | Animalia      | (5)       | Sponges     |
- (a) (A) — (2), (B) — (3), (C) — (4), (D) — (5), (E) — (1)  
 (b) (A) — (1), (B) — (2), (C) — (3), (D) — (5), (E) — (4)  
 (c) (A) — (2), (B) — (5), (C) — (3), (D) — (1), (E) — (4)  
 (d) (A) — (1), (B) — (2), (C) — (3), (D) — (4), (E) — (5)  
 (e) (A) — (2), (B) — (3), (C) — (4), (D) — (1), (E) — (5)
19. Which of the following group of characters is present in all chordates in some or other stage in their life  
 Or  
 Chordates differ from nonchordates in having [Odisha JEE 2012]  
 (a) Mammary glands, hair and gill slits  
 (b) Notochord, gill slits and dorsal tubular nervous system  
 (c) Notochord, scales and dorsal tubular nervous system  
 (d) Gill slits, vertebral column and notochord
20. What is true about Nereis, Scorpion, Cockroach and Silver fish [CBSE PMT 2007]  
 (a) They all have jointed paired appendages  
 (b) They all possess dorsal heart  
 (c) None of them is aquatic  
 (d) They all belong to the same phylum
21. Which of the following pairs are correctly matched [CBSE PMT 2007]
- | Animals |            | Morphological features |
|---------|------------|------------------------|
| (A)     | Crocodile  | — 4-Chambered heart    |
| (B)     | Sea Urchin | — Parapodia            |
| (C)     | Obelia     | — Metagenesis          |
| (D)     | Lemur      | — Thecodont            |
- (a) A, C and D (b) B, C and D  
 (c) Only A and D (d) Only A and B
22. Which one of the following is matching set of a phylum and its three examples [CBSE PMT 2006]  
 (a) Mollusca-Loligo, Teredo, Octopus  
 (b) Porifera-Spongilla, Euplectella, Pennatula  
 (c) Cnidaria-Bonellia, Physalia, Aurelia  
 (d) Platyhelminthes-Planaria, Schistosoma, Enterobius
23. Which is living fossil [NCERT; MP PMT 2000]  
 (a) Coelacanth (b) Limulus  
 (c) Sphenodon (d) All of these

24. The group 'amniota' includes  
[EAMCET 1998; KCET 1999; Wardha 2005]  
(a) Birds and reptiles  
(b) Birds and mammals  
(c) Reptiles and mammals  
(d) Reptiles, birds and mammals
25. The animal group, where the adults are degenerated but larvae are well developed, is  
[CPMT 1999]  
(a) Agnatha (b) Tunicates  
(c) Amphibians (d) Cephalo chordates
26. Which one of the following statements is incorrect  
[CBSE PMT 2006]  
(a) In insects, circulating body fluids serve to distribute oxygen to tissues  
(b) The principle of countercurrent flow facilitates efficient respiration in gills of fishes  
(c) The residual air in lungs slightly decreases the efficiency of respiration in mammals  
(d) The presence of non-respiratory air sacs, increases the efficiency of respiration in birds
27. Which of the following statement is true [Kerala PMT 2006]  
(a) All living members of class cyclostomata are parasites on some fishes  
(b) There are about 2,000 species in the class osteichthyes  
(c) Clona belongs to the subphylum cephalochordata  
(d) Arthropods are diploblastic animals  
(e) *Ascaris lumbricoides* is a flat worm
28. Heterocercal tail is found in [RPMT 2002]  
(a) Cartilaginous fishes (b) Bony fishes  
(c) Whale (d) Amphibians
29. Stenohaline fishes are represented by [MP PMT 2002]  
(a) Fresh water fishes only  
(b) Marine fishes only  
(c) Those which can tolerate a narrow range of salinity in water only  
(d) Those which can tolerate a wide range of salinity in water
30. Fishes having swim bladder, which do not have direct communication with the exterior and where resorbent and secretory part is not sharply separated from one another are called as [MP PMT 2002]  
(a) Physostomes (b) Physoclists  
(c) Euphysoclists (d) Paraphysoclists
31. Which one of the following combination is generally recommended for composite fish farming in India  
[MP PMT 2001]  
(a) Catla, Cyprinus, Clarias  
(b) Catla, Labeo, Cirrhinus  
(c) Cirrhinus, Cyprinus, Channa  
(d) Clarias, Chanos, Cyprinus
32. Which type of coelom is found in frog [RPMT 2001]  
(a) Enterocoel (b) Schizocoel  
(c) Pseudocoel (d) Haemocoel
33. Which of the following statements are true / false  
A. In *Torpedo* the electric organs are capable of generating strong electric shock to paralyze the prey  
B. Bony fishes use pectoral, pelvic, dorsal, anal and caudal fins in swimming  
C. Amphibian skin is moist and has thick scales  
D. Birds are poikilothermous animals  
E. The most unique mammalian characteristic is the presence of milk producing mammary glands by which the young ones are nourished  
[Kerala PMT 2006; CBSE PMT 2014]  
(a) A, B and C are true; D, E are false  
(b) A, B and E are true; C and D are false  
(c) A, D and E are true; B and C are false  
(d) A, B and D are false; C and E are true  
(e) Only D is true; A, B, C and E are false
34. Which of the following snake is not poisonous  
[AIIMS 2000; CPMT 2001]  
(a) *Naja naja* (b) Python  
(c) *Bungarus* (d) *Hydrophis*
35. Limbless lizard is [MP PMT 2000]  
(a) *Draco* (b) *Ophisaurus*  
(c) *Amblyrhynchus* (d) *Moloch*
36. Reptiles share which of the following character with birds and mammals [Pb. PMT 2000; CBSE PMT 2002]  
(a) Amnion (b) Diaphragm  
(c) Homeothermy (d) All of these
37. In which of the following subclasses of reptiles, the skull has a solid roof [MP PMT 2002]  
(a) Anapsida (b) Diapsida  
(c) Synapsida (d) Parapsida
38. Which of the following bird is viviparous [RPMT 1999]  
(a) Penguin (b) Humming bird  
(c) Albatross (d) None of these
39. Which of the following sets is of flightless birds  
[NCERT; MHCET 2002; Kerala PMT 2010]  
(a) Penguin, Pheasant, Fowl, Rhea, Kiwi, Moa, Ostrich  
(b) Emu, Penguin, Rhea, Kiwi, Moa, Cassowary, Ostrich  
(c) Albatross, Humming bird, Falcon, Hawk, Emu  
(d) Ostrich, Emu, Kiwi, Falcon, Albatross
40. Which is the common character between all the mammals [BHU 1999]  
(a) They are oviparous  
(b) They are herbivorous  
(c) They are carnivorous  
(d) They have seven cervical vertebrae
41. Find the odd example [KCET 2007]  
(a) Sea lily (b) Sea fan  
(c) Sea cucumber (d) Sea urchin
42. Annual migration does not occur in the case of [CBSE PMT 2006]  
(a) Salamander (b) Arctic tern  
(c) Salmon (d) Siberian crane

43. Match the following

Column I		Column II	
A.	<i>Euplectella</i>	1.	Sea pen
B.	<i>Physalia</i>	2.	Pinworm
C.	<i>Pennatula</i>	3.	Venus flower basket
D.	<i>Enterobius</i>	4.	Midwife toad
E.	<i>Alytes</i>	5.	Portuguese man of war

[MP PMT 1994; BHU 2001;  
Kerala PMT 2007, 09]

- (a) A-5, B-4, C-3, D-2, E-1  
 (b) A-5, B-3, C-4, D-2, E-1  
 (c) A-4, B-5, C-1, D-2, E-3  
 (d) A-3, B-5, C-1, D-2, E-4  
 (e) A-2, B-1, C-3, D-4, E-5

44. During its life cycle, *Fasciola hepatica* (Liver Fluke) infects its intermediate host and primary host at the following larval stages respectively [CBSE PMT 2003]

- (a) Redia and miracidium  
 (b) Cercaria and redia  
 (c) Metacercaria and cercaria  
 (d) Miracidium and metacercaria

45. Sea cows are aquatic mammals included under

[MP PMT 2001]

- (a) Lagomorpha (b) Pinnipedia  
 (c) Cetacea (d) Sirenia

46. Given below are four matchings of an animal and its kind of respiratory organ

1. Silver Fish – trachea, 2. Scorpion – book lung, 3. Sea squirt – pharyngeal gills, 4. Dolphin – skin [CBSE PMT 2003]

- (a) 3 and 4 (b) 1 and 4  
 (c) 1, 2 and 3 (d) 2 and 4

47. *Sycon* belongs to a group of animals, which are best described as [CBSE PMT 2003]

- (a) Multicellular having tissue organization, but not body cavity  
 (b) Unicellular or acellular  
 (c) Multicellular without any tissue organization  
 (d) Multicellular with a gastrovascular system

48. The correct route through which *Ascaris* passes to complete its life cycle after infecting a fresh host is

[BHU 1999; MP PMT 2013]

- (a) Intestine → Liver → Heart → Lung → Pharynx → Gullet → Stomach → Intestine  
 (b) Outside → Intestine → Liver → Heart → Lung → Pharynx → Gullet → Intestine  
 (c) Intestine → Liver → Heart → Lung → Pharynx → Gullet → Stomach → Intestine → Outside → Intestine  
 (d) Outside → Intestine → Liver → Heart → Lung → Pharynx → Gullet → Stomach → Intestine → Outside

49. Cockroach and earthworm have common type of

[Pb. PMT 2004]

- (a) Heart (b) Nerve cord  
 (c) Nephridia (d) Spermathecae

50. Fertilization in earthworm is

[RPMT 1999]

- (a) Cross fertilization (b) Mutual fertilization  
 (c) Self fertilization (d) None of these

51. Choose the correct combination of the following [CPMT 2000]

- (a) Annelida and porifera-phylla  
 (b) Aves and chordata-classes  
 (c) Mollusca and hydrozoa-classes  
 (d) Oligochaeta and arthropoda-phylla

52. Maximum nutritional diversity is found in the group

[CBSE PMT (Pre.) 2012]

- (a) Fungi (b) Animalia  
 (c) Monera (d) Plantae

53. Phylum annelida resembles mollusca in embryonic features because both have [MP PMT 1999]

- (a) Spiral cleavage and mesoderm formation  
 (b) Identical conspicuous segmentation in body, muscles and nervous system  
 (c) Meroblastic cleavage and ectoderm formation  
 (d) Special type of mouth parts

54. The group that does not fit into this category [MP PMT 1993]

- (a) Amphibia (b) Reptiles  
 (c) Aves (d) Mammals

55. In bioluminescence storage, energy changes into [AFMC 2002]

- (a) Light energy (b) Radiant energy  
 (c) Chemical energy (d) Mechanical energy

56. The main difference between Gymnophiona (Apoda) and Urodela is that Urodela

- (a) Have two auricles and one ventricle  
 (b) Have smooth moist skin  
 (c) Have a cloaca  
 (d) Respire by lungs in the adult stage

57. Body cavity surrounding alimentary canal but it is not lined by cellular layer in which of the following [BHU 2003]

- (a) Nematodes (b) Platyhelminthes  
 (c) Annelids (d) Echinoderms

58. Match the items in column I with column II and choose the correct option

Column I		Column II	
A.	Binary fission	1.	Algae
B.	Zoospore	2.	<i>Amoeba</i>
C.	Conidium	3.	<i>Hydra</i>
D.	Budding	4.	<i>Penicillium</i>
E.	Gemmules	5.	Sponge

[Kerala PMT 2010]

- (a) A-1; B-4; C-5; D-3; E-2 (b) A-2; B-1; C-4; D-3; E-5  
 (c) A-2; B-4; C-3; D-5; E-1 (d) A-1; B-4; C-3; D-2; E-5  
 (e) A-4; B-1; C-3; D-5; E-2



59. In which one of the following the genus name, its two characters and its class/phylum are correctly matched

[NCERT; CBSE PMT (Pre.) 2011]

	Genus name	Two characters	Class/Phylum
(a)	Aurelia	(a) Cnidoblasts	Coelenterata
		(b) Organ level of organization	
(b)	Ascaris	(a) Body segmented	Annelida
		(b) Males and females distinct	
(c)	Salamandra	(a) A tympanum represents ear	Amphibia
		(b) Fertilization is external	
(d)	Pteropus	(a) Skin possesses hair	Mammalia
		(b) Oviparous	

60. Sinking of zooplankton during the day and rising to the surface at night is an example of [AIIMS 2010]

(a) Circinal rhythm (b) Circadian rhythm  
(c) Tidal rhythm (d) None of these

61. Which one of the following is not correctly matched

[WB JEE 2011]

(a) Sycon – canal system (b) Star fish – radial symmetry  
(c) Ascaris – flame cell (d) Prawn – haemocoel

62. Match the following and select the correct answer

Column I	Column II
A. Choanocytes	1. Platyhelminthes
B. Cnidoblasts	2. Ctenophora
C. Flame cells	3. Porifera
D. Nephridia	4. Coelenterata
E. Comb plates	5. Annelida

[Kerala PMT 2010]

(a) A-2, B-1, C-4, D-5, E-3 (b) A-2, B-4, C-1, D-5, E-3  
(c) A-5, B-1, C-3, D-2, E-4 (d) A-3, B-4, C-1, D-5, E-2  
(e) A-3, B-1, C-4, D-5, E-2

63. Which one of the following statements about all the four of Spongilla, Leech, Dolphin and Penguin is correct

[CBSE PMT (Pre.) 2010]

(a) All are bilaterally symmetrical  
(b) Penguin is homoiothermic while the remaining three are poikilothermic  
(c) Leech is a fresh water form while all others are marine  
(d) Spongilla has special collared cells called choanocytes, not found in the remaining three

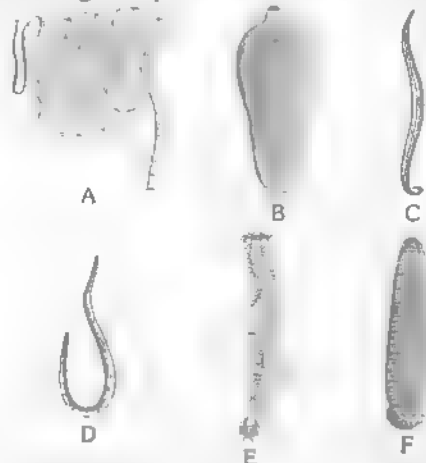
64. Animals possess nerve networks or nervous systems to respond to their environment. But the single celled Amoeba does not possess any nerve cell, so, how it come to know whether a particle it encounters is a grain or sand and not its dinner [AIIMS 2009]

(a) By chemotaxis (b) By skin  
(c) By hormones (d) All of these

65. Retractable claws are found in [MP PMT 2013]

(a) Cat and Lion (b) Leopard  
(c) Hyaena (d) All of the above

66. Identify the names of the following figure A, B, C, D, E and F from the given option [NCERT]



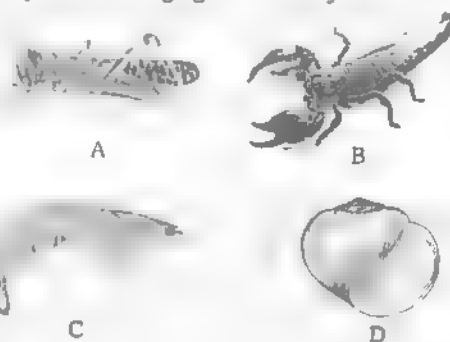
(a) A – Tape worm; B – Liver fluke; C – Male Roundworm; D – Female Roundworm; E – Nereis; F – Hirudinaria

(b) A – Tape worm; B – Liver fluke; C – Female Roundworm; D – Male Roundworm; E – Nereis; F – Hirudinaria

(c) A – Tape worm; B – Liver fluke; C – Male Roundworm; D – Female Roundworm; E – Hirudinaria; F – Nereis

(d) A – Tape worm; B – Liver fluke; C – Female Roundworm; D – Male Roundworm; E – Hirudinaria; F – Nereis

67. Identify the following figures correctly [NCERT]



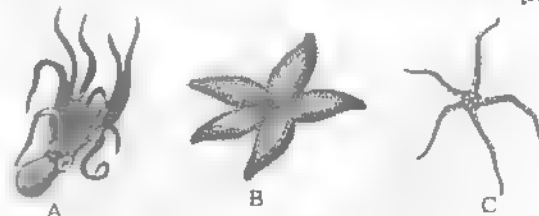
(a) A – Butterfly, B – Scorpion, C – Prawn, D – Pila

(b) A – Locust, B – Scorpion, C – Prawn, D – Snail

(c) A – Locust, B – Prawn, C – Scorpion, D – Pila

(d) A – Locust, B – Scorpion, C – Prawn, D – Pila

68. Identify the names of the following figure from the given option [NCERT]



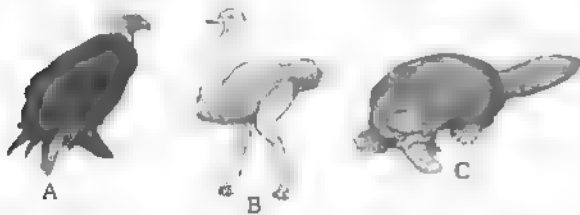
(a) A – Ophiura, B – Asterias, C – Octopus

(b) A – Octopus, B – Asterias, C – Ophiura

(c) A – Octopus, B – Asterias, C – Ascidia

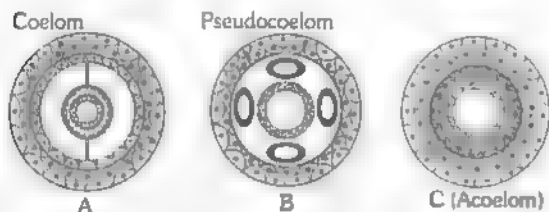
(d) A – Octopus, B – Ascidia, C – Ophiura

69. Identify the name of given animals with their respective classes [NCERT]



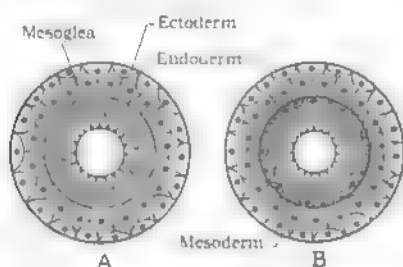
- (a) A – Neophron, Aves; B – Struthio, Reptilia; C – Ornithorhynchus, Mammalia  
 (b) A – Neophron, Aves; B – Struthio, Aves; C – Ornithorhynchus, Aves  
 (c) A – Neophron, Aves; B – Struthio, Mammalia; C – Ornithorhynchus, Mammalia  
 (d) A – Neophron, Aves; B – Struthio, Aves; C – Ornithorhynchus, Mammalia

70.



In which phylum A, B and C are found [NCERT]

- (a) Sponges, Aschelminthes, Platyhelminthes respectively  
 (b) Aschelminthes, Platyhelminthes, Annelids respectively  
 (c) Platyhelminthes, Annelids, Aschelminthes respectively  
 (d) Annelids, Aschelminthes, Platyhelminthes respectively
71. The given figure shows the germ layers. The animals having structures shown in the figure are respectively known as [NCERT]



- (a) Triploblastic, Triploblastic (b) Diploblastic, Diploblastic  
 (c) Triploblastic, Diploblastic (d) Diploblastic, Triploblastic
72. Identify the symmetry of animals A and B respectively [NCERT]

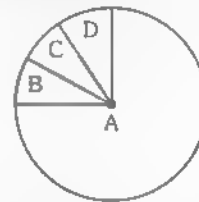


- (a) Radial, Radial (b) Bilateral, Bilateral  
 (c) Radial, Bilateral (d) Bilateral, Asymmetrical

73. Select the Taxon mentioned that represents both marine and fresh water species [CBSE PMT 2014]

- (a) Cephalochordata (b) Cnidaria  
 (c) Echinoderms (d) Ctenophora

74. Given below is the representation of the extent of global diversity of Invertebrates. What groups the four portions (A-D) represent respectively [CBSE PMT 2014]



Options

	A	B	C	D
(a)	Molluscs	Other animal groups	Crustaceans	Insects
(b)	Insects	Molluscs	Crustaceans	Other animal Groups
(c)	Insects	Crustaceans	Other animal groups	Molluscs
(d)	Crustaceans	Insects	Molluscs	Other animal group

75. Which of the following characteristics is mainly responsible for diversification of insects of land

[AIPMT (Cancelled) 2015]

- (a) Bilateral symmetry (b) Exoskeleton  
 (c) Eyes (d) Segmentation

76. Which of the following characteristic features always holds true for the corresponding group of animals

[NEET (Phase-I) 2016]

(a)	Cartilaginous endoskeleton	Chondrichthyes
(b)	Viviparous	Mammalia
(c)	Possess a mouth with an upper and a lower jaw	Chordata
(d)	3 – chambered heart with one incompletely divided ventricle	Reptilia

77. Which one of the following characteristics is **not** shared by birds and mammals [NEET (Phase-I) 2016]

- (a) Ossified endoskeleton (b) Breathing using lungs  
 (c) Viviparity (d) Warm blooded nature

78. Chitin is chemically a polymer of [Uttaranchal PMT 2001]  
 Or

The chitinous exoskeleton of arthropods is formed by the polymerisation of [AIPMT 2015]

- (a) N-acetyl gluconic acid (b) N-acetyl glucosamine  
 (c) N-acetyl muramic acid (d) None of these

79. Which of the following statements(s) is/are correct about *Macropus* spp [WB JEE 2016]  
 (a) They are metatherian mammals  
 (b) They are only found in Austria  
 (c) They have true placenta  
 (d) External ears are present
80. An important characteristic that hemichordates share with Chordates is [NEET 2017]  
 (a) Absence of notochord (b) Ventral tubular nerve cord  
 (c) Pharynx with gill slits (d) Pharynx without gill slits
81. Which among these is the correct combination of aquatic mammals [NEET 2017]  
 (a) Seals, Dolphins, Sharks (b) Dolphins, Seals, Trygon  
 (c) Whales, Dolphins, Seals (d) Trygon, Whales, Seals

## R Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

- (a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion  
 (b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion  
 (c) If the assertion is true but the reason is false  
 (d) If both the assertion and reason are false  
 (e) If the assertion is false but reason is true

1. Assertion : Sponges have tissue level of organization.  
 Reason : Sponges are multicellular.
2. Assertion : In mollusca, circulatory system is of closed type.  
 Reason : The blood of mollusca contains haemoglobin [AIIMS 1995]
3. Assertion : *Leucosolenia* shows ascon type of canal system.  
 Reason : In *Leucosolenia* water passes through ostia → spongocoel → osculum.
4. Assertion : Sponges do not show any animal nature.  
 Reason : Sponges are sessile with no apparent way of capturing food or eliminating water.
5. Assertion : The duck-billed *Platypus* and the spiny ante-eater, both are egg-laying animals yet they are grouped under mammals.  
 Reason : Both of them have seven cervical vertebrae and 12 pairs of cranial nerves. [AIIMS 2005]
6. Assertion : Tapeworm, roundworm and pinworm are endoparasites of human intestine  
 Reason : Improperly cooked food is the source of all intestinal infections. [AIIMS 2004, 08]
7. Assertion : Coelenterates are known as Radiata.  
 Reason : Coelenterates are bilaterally symmetrical.
8. Assertion : *Hydra* is green coloured.  
 Reason : Green colour is due to the presence of chlorophyll in their body wall.
9. Assertion : Nerve cells in coelenterata have complete co-ordination in their body.  
 Reason : True nerve cells occur for the first time in coelenterate.

10. Assertion : King cobra is adaptive to oriental realm.  
 Reason : Wallace line prevents interaction of king cobra and kangaroo. [AIIMS 2009]
11. Assertion : Bats and whales are classified as mammals.  
 Reason : Bats and whales have four-chambered heart. [AIIMS 2003, 08]
12. Assertion : All birds, except the ones like koel (cuckoo) build nests for retiring and taking rest during night time (day time for nocturnal).  
 Reason : Koel lays its eggs in the nests of tailor bird. [AIIMS 2003]
13. Assertion : *Obelia* is dimorphic in nature.  
 Reason : *Obelia* shows polyp and gonangia form.
14. Assertion : Coelenterates show alternation of generation.  
 Reason : In coelenterates, asexual generation is followed by sexual generation.
15. Assertion : Lateral line system is found in fishes and aquatic larval amphibians.  
 Reason : Lateral line system has receptor of sensory cells derived from ectoderm. [AIIMS 2002]
16. Assertion : *F. hepatica* undergoes both aerobic and anaerobic respiration.  
 Reason : *Fasciola* respire only in absence of oxygen.
17. Assertion : *Plasmodium vivax* is responsible for malaria.  
 Reason : Malaria is caused by polluted water. [AIIMS 2001]
18. Assertion : Birds have one ovary.  
 Reason : This reduces the body weight for flight. [AIIMS 1999]
19. Assertion : A shark can stay at a desired level in water without swimming.  
 Reason : It has a buoyancy-regulating organ called as the swim bladder. [AIIMS 1999]
20. Assertion : Sponges belong to Porifera.  
 Reason : Sponges have canal system. [AIIMS 1998]
21. Assertion : There is no chance of malaria to a man on the bite of male *Anopheles* mosquito.  
 Reason : It carries a non-virulent strain of *Plasmodium*. [AIIMS 1998]
22. Assertion : Cold blooded animals do not have fat layer.  
 Reason : Cold blooded animals use their fat for metabolic process during hibernation. [AIIMS 1997]
23. Assertion : Acraniata is a group of organisms which do not have distinct cranium.  
 Reason : It includes small marine forms without head. [AIIMS 1997]
24. Assertion : The skeleton of sponges is made up of spicules.  
 Reason : Composition of spicules help in classification of sponges. [AIIMS 1995]

25. Assertion : Cephalization is advantageous to an animal.  
Reason : It improves the appearance of the animal.  
(AIIMS 1994)
26. Assertion : Blood is colourless in the insects.  
Reason : Insect blood has no role in  $O_2$  transport.  
(AIIMS 1994)
27. Assertion : Lophodont dentition is also found in the mammals.  
Reason : Lophodont type of dentition is specially for herbivore mammals.
28. Assertion : 'Calabar swelling' is caused by 'eye worm'.  
Reason : *Loa loa* is called the 'eye worm'.
29. Assertion : Metamerism is the characteristic of annelida.  
Reason : Metamerism is one type of body segmentation.
30. Assertion : Blood is red in annelida.  
Reason : RBCs are absent in them.
31. Assertion : Baleen is an example of aquatic adaption.  
Reason : Baleen is a balloon like structure present beneath the skin of mammals.
32. Assertion : Spermathecae are the main part of reproductive system of annelida.  
Reason : Spermathecae help in sperm transfer.
33. Assertion : Coprophagy is the characteristic of mammal.  
Reason : Coprophagy is found in all mammals.
34. Assertion : Both true ribs and floating ribs are present in mammals.  
Reason : By nature, sternal ribs are true ribs as, they possess all the characters of ribs.
35. Assertion : Cutaneous glands help in regulation of body temperature.  
Reason : Cutaneous glands are produced from stratum germinativum.
36. Assertion : Annelids are ureotelic.  
Reason : Only excretory product of annelids is uric acid.
37. Assertion : Open circulatory system is found in most arthropods.  
Reason : Arthropods contain haemolymph which directly bathes internal tissues and organ  
(AIIMS 2010)
38. Assertion : The birds can maintain a constant body temperature.  
Reason : Birds possess feathers covering their body.
39. Assertion : Moulting or ecdysis occurs only in invertebrates.  
Reason : In birds, moulting usually takes an average time of six weeks.
40. Assertion : Birds have no mammary gland.  
Reason : Pigeons secrete 'pigeon's milk'.
41. Assertion : The fangs of snake is the maxillary teeth.  
Reason : The poison apparatus in snake consists of poison gland, ducts and fangs.
42. Assertion : In reptiles, hemipenes is present.  
Reason : Hemipenes is the combination of both ovary and penis.
43. Assertion : Parental care is seen in amphibians.  
Reason : Amphibians have taken several method to protect their eggs and offspring.
44. Assertion : In frogs, the entire skin serves as tangoreceptors.  
Reason : Tactile organs and patches are present throughout the skin of frog.
45. Assertion : "Lymph heart" is present in frog.  
Reason : Lymph in frog is circulated by lymph heart.
46. Assertion : In frog, most of the absorption takes place in intestine.  
Reason : The intestine in frog is the coiled structure.
47. Assertion : Amphibians are poikilothermal.  
Reason : Amphibians often undergoes summer sleep.
48. Assertion : In fishes, heart is venous.  
Reason : Only veins are present in the heart of fishes.
49. Assertion : Ampullae of lorenzini are found beneath the skin of head region in fishes.  
Reason : Ampullae of lorenzini acts as receptors.
50. Assertion : Lateral line canal is one of the main characteristics of fishes.  
Reason : Lateral line canal is a system of sense organ concerned with life in water.
51. Assertion : Characters of cyclostomes show an advance over *Amphioxus*.  
Reason : Cyclostomes have some degenerated characters.
52. Assertion : *Amphioxus* has a simple organization compared to vertebrates.  
Reason : Many important cranial structures are lacking in *Amphioxus*.
53. Assertion : Glochidium larva rapidly disperse to a great distance  
Reason : Glochidium is parasitic on fish.
54. Assertion : Respiration in *Amphioxus* is done by both water and blood.  
Reason : *Amphioxus* is aquatic and possesses blood.
55. Assertion : Detorsion is the characteristic of mollusca.  
Reason : Detorsion is an arrested stage of torsion.
56. Assertion : Tube feet are characteristic organs of echinodermata  
Reason : Tube feet have an important role in respiration.

57. Assertion : Endostyle is present at the pharyngeal groove of the midventral wall of the pharynx of *Amphioxus*.  
Reason : Endostyle has an important role in respiration.
58. Assertion : *Herdmania* has digestion mechanism like higher group of animals.  
Reason : Liver of *Herdmania* possess several enzymes required for digestion.
59. Assertion : In *Balanoglossus* notochord is replaced by pygochord.  
Reason : Pygochord supports abdominal region.
60. Assertion : Water vascular system is the characteristic of echinoderms.  
Reason : Main function of water vascular system is locomotion.
61. Assertion : *Balanoglossus* is often considered as "acorn worms".  
Reason : The word 'acorn worm' has no meaning.

## Answers

### Important terms and classification of animals

1	c	2	b	3	a	4	b	5	c
6	c	7	c	8	d	9	b	10	a
11	a	12	d	13	b	14	c	15	c
16	c	17	a	18	c	19	b	20	b
21	a	22	a	23	b	24	b	25	c
26	b	27	d	28	a	29	c	30	b
31	b	32	a	33	c	34	c	35	c
36	d	37	d	38	d	39	a	40	c
41	a	42	c	43	d	44	c	45	b

### Phylum-Porifera

1	c	2	a	3	b	4	a	5	a
6	a	7	b	8	a	9	b	10	b
11	a	12	d	13	d	14	a	15	b
16	a	17	d	18	b	19	d	20	a
21	d	22	b	23	b	24	d	25	c
26	a	27	d	28	b	29	a	30	d
31	a	32	a	33	d	34	a	35	b
36	b	37	a	38	c	39	b	40	c
41	d	42	a	43	c	44	b	45	a
46	b	47	c	48	c	49	a	50	d
51	d	52	b	53	d	54	b	55	a
56	c								

### Phylum-Coelenterata

1	a	2	b	3	b	4	a	5	b
6	d	7	c	8	b	9	c	10	b
11	b	12	c	13	d	14	c	15	a
16	b	17	d	18	b	19	a	20	a
21	c	22	a	23	d	24	b	25	b
26	b	27	d	28	d	29	c	30	a
31	c	32	d	33	d	34	a	35	b
36	c	37	d	38	c	39	a	40	a
41	a	42	d	43	b	44	c	45	b
46	a	47	c	48	d	49	b	50	a
51	d	52	c	53	d	54	c	55	b
56	d	57	b	58	b	59	d	60	d
61	b	62	d	63	c	64	b	65	a
66	d	67	d	68	a	69	d	70	a
71	a	72	a	73	d	74	d	75	a
76	b	77	a	78	d	79	b	80	c
81	d	82	a	83	c	84	b	85	d
86	b	87	d						

### Phylum-Platyhelminthes

1	a	2	a	3	d	4	b	5	b
6	b	7	d	8	a	9	b	10	d
11	b	12	b	13	d	14	c	15	d
16	c	17	d	18	a	19	c	20	a
21	a	22	a	23	a	24	d	25	b
26	b	27	c	28	a	29	d	30	a
31	d	32	a	33	c	34	b	35	c
36	b	37	a	38	c	39	b	40	a
41	a	42	a	43	d	44	c	45	d
46	a	47	a	48	d	49	b	50	b
51	b	52	a	53	c	54	b	55	c

### Phylum-Nemathelminthes

1	d	2	a	3	b	4	d	5	a
6	c	7	b	8	a	9	a	10	c
11	b	12	a	13	c	14	b	15	b
16	c	17	d	18	d	19	b	20	a
21	a	22	c	23	a	24	d	25	d
26	d	27	c	28	c	29	c	30	c
31	c	32	a	33	b	34	d	35	a
36	c	37	c	38	d	39	a	40	a
41	d	42	d	43	a	44	c	45	d

46	b	47	a	48	d	49	b	50	c
51	c	52	b	53	d	54	d	55	b
56	b								

### Phylum-Annelida

1	d	2	b	3	d	4	c	5	a
6	a	7	b	8	b	9	c	10	c
11	c	12	d	13	a	14	c	15	c
16	c	17	d	18	b	19	a	20	c
21	b	22	b	23	a	24	a	25	d
26	c	27	b	28	b	29	a	30	c
31	d	32	c	33	b	34	a	35	c
36	c	37	b	38	d	39	a	40	b
41	c	42	c	43	a	44	b	45	c
46	d	47	c	48	c	49	c	50	a
51	b	52	b	53	a	54	b	55	a
56	d	57	b	58	a	59	b	60	d
61	d	62	b	63	b	64	d	65	c
66	a	67	b	68	d	69	c	70	b
71	a	72	c	73	a	74	d	75	a
76	a	77	b	78	a	79	d	80	a
81	a	82	a	83	d	84	a	85	c
86	b	87	b	88	c	89	b	90	c
91	d	92	a	93	a	94	b	95	c
96	b	97	d	98	d	99	d	100	c
101	c	102	a	103	e	104	c	105	b
106	c	107	d	108	a	109	d	110	b
111	c	112	d	113	c	114	d	115	c

### Phylum-Arthropoda

1	b	2	d	3	c	4	b	5	c
6	c	7	d	8	a	9	a	10	c
11	a	12	a	13	b	14	a	15	d
16	a	17	c	18	e	19	b	20	a
21	b	22	b	23	a	24	c	25	b
26	d	27	d	28	c	29	c	30	d
31	a	32	d	33	c	34	c	35	b
36	d	37	c	38	c	39	c	40	b
41	b	42	c	43	b	44	d	45	a
46	d	47	b	48	d	49	d	50	d
51	b	52	b	53	d	54	c	55	a
56	d	57	c	58	d	59	a	60	a
61	a	62	c	63	a	64	d	65	b

66	c	67	b	68	a	69	a	70	b
71	c	72	a	73	d	74	a	75	d
76	d	77	c	78	c	79	b	80	d
81	c	82	d	83	b	84	c	85	d
86	b	87	d	88	c	89	b	90	d
91	a	92	a	93	d	94	c	95	d
96	b	97	b	98	d	99	c	100	a
101	a	102	d	103	c	104	c	105	a
106	b	107	b	108	b	109	c	110	c
111	a	112	a	113	b	114	a	115	d
116	d	117	a	118	b	119	c	120	c
121	e	122	b	123	c	124	d	125	b
126	c	127	b	128	a	129	d	130	b
131	a	132	d	133	a	134	c	135	b
136	b	137	b	138	a	139	b	140	b
141	b	142	a	143	d	144	c	145	a
146	b	147	b	148	c	149	a	150	b
151	d	152	a	153	b	154	c	155	b
156	d	157	c	158	a	159	c	160	a
161	a	162	c	163	c	164	c	165	b
166	c	167	b	168	a	169	d	170	c
171	d	172	d	173	b	174	a	175	c
176	c	177	c	178	a	179	d	180	d
181	a	182	c	183	b	184	b	185	c
186	d	187	d	188	d	189	b	190	c
191	a	192	a	193	a	194	b	195	b
196	a	197	a	198	d	199	a	200	b
201	b	202	b						

### Phylum-Mollusca

1	a	2	a	3	b	4	c	5	c
6	a	7	a	8	d	9	a	10	c
11	c	12	c	13	c	14	a	15	a
16	a	17	b	18	d	19	c	20	c
21	b	22	c	23	d	24	d	25	a
26	a	27	b	28	a	29	b	30	a
31	c	32	b	33	d	34	c	35	b
36	a	37	c	38	a	39	a	40	d
41	b	42	d						

### Phylum-Echinodermata

1	d	2	c	3	b	4	d	5	c
6	a	7	d	8	d	9	c	10	b
11	a	12	b	13	a	14	c	15	a

16	c	17	b	18	a	19	d	20	d
21	c	22	c	23	d	24	d	25	b
26	b	27	a	28	c	29	c	30	a
31	a	32	c	33	d	34	d	35	d
36	b								

**Phylum-Chordata**

1	c	2	d	3	d	4	c	5	b
6	c	7	b	8	c	9	a	10	c
11	c	12	b	13	a	14	c	15	a
16	d	17	b	18	c	19	a	20	c
21	b	22	c	23	a	24	d	25	b
26	e	27	c	28	b	29	a	30	a
31	a	32	a	33	c	34	b	35	b
36	d	37	c	38	d	39	b	40	c
41	a	42	c	43	a	44	d	45	c
46	d	47	b	48	c	49	a	50	c
51	c	52	a	53	b	54	b		

**Super Class-Pisces**

1	a	2	b	3	a	4	d	5	d
6	d	7	a	8	a	9	d	10	c
11	a	12	c	13	d	14	d	15	a
16	a	17	a	18	b	19	b	20	c
21	b	22	b	23	a	24	c	25	b
26	b	27	b	28	c	29	a	30	b
31	b	32	d	33	b	34	b	35	d
36	a	37	a	38	d	39	a	40	b
41	b	42	a	43	a	44	d	45	c
46	b	47	c	48	c	49	d	50	a
51	c	52	c	53	d	54	a	55	c
56	c	57	b	58	d	59	d	60	a
61	a	62	c						

**Class-Amphibia**

1	b	2	b	3	b	4	b	5	d
6	b	7	d	8	c	9	a	10	a
11	c	12	a	13	c	14	b	15	c
16	a	17	d	18	d	19	d	20	c
21	a	22	a	23	c	24	a	25	c

**Class-Reptilia**

1	c	2	a	3	b	4	a	5	c
6	c	7	c	8	a	9	d	10	a
11	a	12	c	13	c	14	b	15	a
16	b	17	a	18	a	19	b	20	a

21	b	22	d	23	d	24	d	25	a
26	b	27	a	28	c	29	b	30	c
31	a	32	d	33	b	34	d	35	d
36	b	37	d	38	d	39	b	40	a
41	c	42	c	43	b	44	b	45	b
46	d	47	c	48	d	49	a	50	d
51	c	52	b	53	a	54	c	55	c
56	b	57	b	58	d	59	c	60	b
61	d								

**Class-Aves**

1	b	2	c	3	a	4	d	5	a
6	a	7	d	8	c	9	c	10	c
11	a	12	d	13	d	14	c	15	c
16	d	17	a	18	d	19	a	20	a
21	c	22	d	23	c	24	a	25	b
26	d	27	b	28	c	29	b	30	d
31	d	32	c	33	b	34	d	35	b
36	a	37	c	38	d	39	c		

**Class-Mammalia**

1	a	2	c	3	b	4	b	5	d
6	a	7	b	8	b	9	e	10	b
11	a	12	d	13	d	14	b	15	c
16	d	17	b	18	c	19	a	20	b
21	b	22	b	23	d	24	d	25	a
26	d	27	b	28	d	29	b	30	c
31	d	32	c	33	a	34	b	35	b
36	c	37	b	38	d	39	d	40	c
41	c	42	c	43	a	44	b	45	a
46	d	47	a	48	d	49	c	50	d
51	b	52	d	53	c	54	b	55	c
56	c	57	d	58	d	59	b	60	a
61	a	62	d	63	c	64	d	65	a
66	a	67	b	68	d	69	d	70	a
71	d	72	a	73	a	74	b	75	c
76	d	77	b	78	c	79	a	80	b

**NCERT Exemplar Questions**

1	b	2	b	3	b	4	c	5	d
6	c	7	a	8	a	9	a	10	c
11	c	12	b	13	c				

### Critical Thinking Questions

1	c	2	b	3	a	4	e	5	a
6	a	7	b	8	b	9	b	10	a
11	b	12	c	13	c	14	d	15	a
16	b	17	c	18	e	19	b	20	b
21	a	22	a	23	d	24	d	25	b
26	a	27	a	28	a	29	c	30	b
31	b	32	a	33	b	34	b	35	b
36	a	37	a	38	d	39	b	40	d
41	b	42	a	43	d	44	d	45	d
46	c	47	c	48	c	49	d	50	a
51	a	52	b	53	a	54	a	55	a
56	b	57	a	58	b	59	c	60	b
61	c	62	d	63	d	64	a	65	d
66	a	67	d	68	b	69	d	70	d
71	d	72	c	73	b	74	b	75	b
76	a	77	c	78	b	79	ad	80	c
81	c								

### Assertion and Reason

1	e	2	d	3	a	4	e	5	a
6	b	7	c	8	c	9	a	10	b
11	b	12	b	13	a	14	a	15	a
16	c	17	c	18	a	19	d	20	b
21	c	22	b	23	b	24	b	25	c
26	b	27	b	28	b	29	b	30	b
31	c	32	a	33	c	34	b	35	b
36	c	37	a	38	a	39	a	40	b
41	b	42	c	43	a	44	a	45	a
46	b	47	a	48	c	49	b	50	a
51	b	52	a	53	a	54	a	55	b
56	c	57	c	58	a	59	d	60	b
61	c								

## AS Answers and Solutions

### Important terms and classification of animals

11. (a) Echinodermates and chordates are deuterostomous animals, in which blastopore of gastrula forms anus, so anus is formed earlier than mouth.
13. (b) The cell aggregate plan is seen in simplest animals, such as sponge. This plan exhibits essentially cluster of cells with rudimentary of labour amongst them.
18. (c) Blind sac body plan is found in coelenterates and flat worms. In this type of body plan animals has a single opening that act as both mouth and anus.
22. (a) From evolutionary point of view platyhelminthes are first triploblastic animals but do not contain coelom.
23. (b) Whole animal kingdom is classified into two sub-kingdom protozoa and metazoa. Unicellular animals are placed in protozoa while multicellular are included in metazoa.
29. (c) All sponges are aquatic, mostly marine rarely fresh water (e. g. spongilla)
36. (d) True coelom is present in Annelid while platyhelminthes have pseudo (false) coelom called pseudocoelomate animals.
39. (a) In nemathelminthes or round worm, coelom is present but it is derived from blastocoel. It is not lined by peritoneum. This type of coelom is known as pseudocoelom.
41. (a) Veliger, trochophore or glochidium larva are characteristic of mollusca.
44. (c) Metamerism is a condition in which the body is composed of a linear series of similar body segments called metameres or somites. It is found in Annelida, Arthropoda and chordata.

### Phylum-Porifera

7. (b) Many pores are present on the body known as ostia through which water enters into the body. Ostia correspond to mouth of other animals.
8. (a) Choanocytes or collar cells are present only in sponges
9. (b) Sponges have a canal system and they need a continuous current of water flowing through their bodies for respiration, excretion, nutrition and reproduction.



12. (d) Food vacuole is transferred to amoebocytes and digestion is completed there.
13. (d) In *Leucosolenia*, further development results in the formation of stereogastrula or parenchymula larva.
15. (b) *Euplectella* with its imprisoned shrimps makes a good wedding gift in Japan, symbolizing the idea "till death us do part".
16. (a) Water currents produced by choanocytes because they are flagellated.
18. (b) *Spongilla* is known as fresh water sponge.
20. (a) The larva of *Cliona* or boring sponge or sulphur sponges bores through and damages the skeleton of corals and shells of molluscs. It is harmful to pearl industry.
22. (b) Classification of sponges is primarily based on skeleton or spicules.
23. (b) Amphiblastula and stereogastrula are the larval stages of sycon.
24. (d) When bathsponges are dried all its cells are destroyed except spongin fibre.
25. (c) Sponges have excellent regeneration power so each piece develop into complete individual.
26. (a) Archaeocytes may be converted into other types of cells and are also called undifferentiated totipotent cells.
27. (d) The spongin fibres are secreted by cells termed spongioblasts. They are formed of protein collagen and occur as a network.
28. (b) In porifera, bodywall is with outer pinacoderm (ectoderm), inner choanoderm (endoderm) and gelatinous noncellular mesenchyme in between.
29. (a) Food coming through the incoming water is ingested by choanocytes.
32. (a) The course taken by water into the canal system is.  
water from outside  $\xrightarrow[\text{dermal ostia}]{\text{through}}$  incurrent canals  
 $\xrightarrow[\text{prosopyles}]{\text{through}}$  radial canals  $\xrightarrow[\text{apopyles}]{\text{through}}$  spongocoel  
 $\xrightarrow[\text{osculum}]{\text{through}}$  outside.
34. (a) The gemmules are asexual reproductive bodies found in all fresh water and a few marine sponges. They are formed as internal buds and protect the species during unfavourable conditions.
35. (b) Spongin fibres occurs in various forms in the class Demospongiae. It may occur as a cement connecting together the siliceous spicules.
36. (b) Digestion of food takes place partially in choanocytes and partially in wandering amoebocytes.
42. (a) Ascon is the simplest type of canal system, in which the body is thin-walled, bilaterally symmetrical and hollow due to the central cavity known as the spongocoel or gastrovascular cavity.
45. (a) Collar cells occur in sponges and located at the anterior end of each choanocyte.
47. (c) If carmine particles are placed close to osculum of a living sponge, these will be carried away.
49. (a) Sponges are multicellular grade organism.
50. (d) The sponges closely resemble to colonial choanoflagellates belonging to the phylum protozoa. Both possess collared and amoeboid cells.
53. (d) Sponges have numerous mouthlets (ostia) and one exit (osculum).
54. (b) Incurrent canals are communicated to outside through ostia but end blindly at their inner ends. Pinacocytes line these canals throughout.

### Phylum-Coelenterata

4. (a) Metagenesis is alternation of generations found in cnidaria phylum eg. *Obelia*
5. (b) In class scyphozoa of phylum coelenterata, the polyp form is reduced or absent.
8. (b) *Obelia* shows alternation of asexual and sexual phase (both phase are diploid). The asexual phase is represented by the colony while the sexual phase is medusa. The two alternate in life cycle. Such an alternation between asexual and sexual phases is called metagenesis.
9. (c) Sea cucumber is the common name of *Cucumaria*. It is belong to phylum Echinodermata.

13. (d) The ctenophora is a small phylum of marine animals, which are commonly known as comb jellies or sea walnuts. The phylum takes its name from two Greek words, *ketos* = comb and *phoros* = bearing, as the animals possess eight comb like for locomotion. In Ctenophora, asexual reproduction is totally absent.
15. (a) Polyp and medusa are the asexual and sexual phase present respectively in coelenterates  
*Aurelia* (jelly fish) belongs to class Scyphozoa, in which medusoid phase is dominant, polypoid phase absent.
16. (b) Jelly-fishes (*Aurelia*) are the animals which belong to the class scyphozoa of the phylum coelenterata.
17. (d) Special type of cells called nematocytes are present in only coelenterata. These cells are used for food catching, defensive and offensive purposes.
19. (a) Nematoblast (cnidoblast) are sensory in nature and acts as an organ for offense and defence.
20. (a) In *Hydra* the exchange of oxygen and  $CO_2$  and the excretion of waste nitrogenous matter (chiefly ammonia) occur directly by diffusion through cell membrane to outside.
22. (a) Body cavity of hydra is called coelenteron or gastrovascular cavity. It is surrounded by the body wall. The mouth leads into this cavity.
23. (d) Pneumatophore is a gas filled chamber found in *Physalia* which helps in floating.
27. (d) Larval stage is absent in *Hydra*.
29. (c) Coelenterates are diploblastic animals i.e., derived only from two embryonic germ layers. Ectoderm and endoderm. They show radial symmetry.
32. (d) Sea pen are pen-like colonial coelenterates.
34. (a) In hydrozoa, either only polyps are found or polyps and medusae are present. Examples – *Hydra*, *Obelia*, *Physalia* etc.
36. (c) *Physalia* is commonly known as 'portuguese man of war' due to sudden appearance and disappearance like active Navy ships of Portugal which is pelagic, marine swimming animal.
37. (d) Statocyst help to maintain equilibrium in larval stage (medusae) of *Obelia*.
38. (c) Ephyra is a small, medusa like stage in the life cycle of scyphozoans or jelly fish (*aurelia*).
40. (a) Coelenterata (coelom + enteron) or phylum Cnidaria shows both sexual and asexual reproduction. The larval stage are Planula (*Obelia*) and Ephyra (*Aurelia*).
42. (d) Cnidoblasts (nematoblast) are specialised and modified interstitial cells which are found in coelenterate animals. The cnidoblasts are organs of defence and offence.
44. (c) Choanocytes cells is a characteristic feature of sponge which are also known as collar cells.
45. (b) *Hydra* possesses a very primitive nervous system consisting of a synaptic network of bipolar and multipolar nerve cells. Thus, hydra has a nervous system but no brain.
46. (a) *Hydra* has four types of nematocysts. They are penetrants (largest). Volents (smallest) steroline glutinant (small atrichous) and streptoline glutinants (large holotrichous).
50. (a) A unicellular green alga of the genus *zoochlorellae* and *zoaxanthallae* habitually lives in nutritive-muscular cells of *Hydra*.
52. (c) *Corallium rubrum* is the precious red coral of commerce. It is highly valued as it is used for making jewellery.
53. (d) A sexually mature medusa of *obelia* bears four groups of gonads situated on the middle of four radial canal.
55. (b) Stinging cells or cnidocytes having nematocysts which is found in ectoderm.
59. (d) Nematocyst plays an important role in locomotion, food capture both offence and defence.
61. (b) A mechanical stimulation of cnidocil by contact with an object is essential, but not sufficient, for discharge.
62. (d) *Gorgonia* (sea-fan) is an animal. All animals lack cell wall.
64. (b) The hydra has a great power of regeneration, the power of replacing lost tissues. If a living hydra is cut into two or more very small fragments, every fragment develops into a new individual. Basal disc is developed towards lower side and mouth, hypostome and tentacles, developed at upper side in each part whatever is required according.
65. (a) The interstitial cells become active and form germ cells by repeated multiplication which bulge out as gonads.
73. (d) Cnidoblast or nematocysts are derived from interstitial cells of epidermis.
75. (a) The medusa is strictly carnivorous. The food includes minute worms, nematodes, insects, crustaceans, etc.
80. (c) In this method of locomotion of *hydra*, usually the body first extends and then bends over, so that the tentacles attach to the substratum with the help of adhesive atrichous isorhizas.
82. (a) When the body can be divided into two similar halves by one or two vertical planes only, the radial symmetry is called biradial symmetry. It is present in the sea anemone.
86. (b) Ctenophores have certain characteristics in common with the coelenterates, but there is no evidence that they were derived from the latter.
87. (d) During the development in *Hydra*, a solid gastrula is formed. The solid gastrula is neither ciliated nor free swimming because it is still attached to the parent body. This type of gastrula is characteristically called stereogastrula which represents the planula stage of hydra.

### Phylum-Platyhelminthes

1. (a) Flame cell or solenocyte or protonephridia and nephridia are excretory organs of phylum platyhelminthes and annelida respectively.
2. (a) Planaria (*Dugesia*) belong to class Turbellaria of phylum platyhelminthes. Mostly free living flatworms are placed in class Turbellaria.

3. (d) Self fertilization is fusion of male and female gametes (sex cells) produced by the same individual. Self-fertilization occurs in bisexual organisms, including most flowering plants, numerous protozoans, and many invertebrates.  
Flukes are hermaphrodites, meaning each worm has both ovaries and testes. Probably cross fertilization is the rule, but self fertilization is certainly a possibility. In any case, it means that every individual is capable of producing fertilized eggs, certainly an advantage in species in which a high reproductive output is required.
5. (b) In cestodes digestive system is completely absent due to endoparasitic mode of life but it may be present in Trematoda and Turbellaria
6. (b) *Schistosoma* is blood fluke
9. (b) Onchosphere, hexacanth and cysticercus (bladder-worm) are different larval stage of *Taenia-solium*.
13. (d) Solenocytes are flame cells like structures attached within the body of nephridium. Each cell has nucleus, cytoplasm and long flagellum that runs through tubules.
14. (c) In *Fasciola*, Laurer's canal is a temporary vaginal canal, which arise from oviduct during breeding season and act as fertilization tube.
17. (d) Being parasitic in mode of life, locomotory organs are totally absent in *Taenia*.
18. (a) On the basis of body shape and habitat, platyhelminthes are classified into three classes. Turbellaria, Trematoda and cestoda.
20. (a) Among invertebrates upto platyhelminthes (flatworm), they have no coelom and are called acoelomate animals.
24. (d) Planaria/Dugesia is a free living leaf like flatworm found in fresh water. It has high power of regeneration so it is used in regeneration experiments.
25. (b) Ventral surface of *Dugesia*'s body is covered with fine hair like locomotory structure called cilia.
29. (d) *Taenia Solium* is a facultative anaerobe. It decomposes glycogen into  $CO_2$  and fatty acids to liberate energy. However it is also capable of aerobic respiration and utilizes even traces of oxygen when available in host fluids.
30. (a) Platyhelminthes (liver-fluke) are first acoelomate animals, which have organ system organization and bilateral symmetry.
32. (a) Mehlis's glands of Tapeworm are associated with reproductive system. Secretory substance of mehlis's glands act as lubricant.
34. (b) *Taenia* has no digestive system, it obtain digested nutrients (like glucose, amino acid, glycerol) from small intestine of host through body surface with the help of microvilli
36. (b) Hexacanth embryo of *Taenia* is present in ripe proglottids or gravid proglottids, which is covered by shell structure, called onchosphere.
37. (a) *Schistosoma* lives in hepatic portal system and mesenteric blood vessels of human beings, so commonly called "blood fluke".
38. (c) Fertilized egg of *Taenia solium* develops into an embryo that gets covered by a shell. The shelled embryos are called onchospheres. Secondary host acquires infection by ingesting the onchosphere, released from *Taenia*.
39. (b) *Hymenolepis nana*, belong to class cestoda and generally known as dwarf tapeworm, which length about 2-4.5 c.m. Life cycle of *Hymenolepis* is monogenetic.
40. (a) Life history of liver fluke is digenetic, primary host is liver of sheep and secondary host is snail.
41. (a) *Schistosoma mansoni* is the common human blood fluke. It belongs to class Trematoda of platyhelminthes. Blood fluke is digenetic, primary host is man and secondary host is snail.
42. (a) Miracidium, sporocyst and cercaria are different form of larva in life history of *schistosoma*.
43. (d) Mature proglottids are in the middle having reproductive organs both male and female.
45. (d) Shelled hexacanth larva in pig muscle, absorbs a large amount of watery fluid from host tissue and grows to a spherical pea sized, sac like cyst called bladder worm or cysticercus.
46. (a) Mostly flatworms are included in class Turbellaria of phylum platyhelminthes e.g. planaria
47. (a) Anus is absent in *Fasciola hepatica*. Undigested food material is probably ejected through the mouth or diffused into excretory system
49. (b) Hexacanth moves in the body and ultimately settles in the muscles of secondary host (pig). Here it forms an encysted bladderworm or cysticercus. Cysticercus remain viable for upto six months.
50. (b) Different larval stage of liver fluke are found in following sequence  
Miracidium → Sporocyst → Redia → Cercaria → Metacercaria
55. (c) *Taenia solium* (Tape worm) and *Echinococcus* (Dog Tapeworm) are endoparasite. They obtain their food from host through body surface. So lacks alimentary canal.

### Phylum-Nemathelminthes

1. (d) *Enterobius vermicularis* is the human 'pin worm' or 'seat worm' and is perhaps the most common parasitic nematode of man throughout the world.
2. (a) Pineal setae is the main characteristic of male *Ascaris* and situated on the dorsal side of cloaca.
4. (d) *Ascaris* is monogenetic so it completes its life cycle in single host i.e., man.
5. (a) *Taenia* is grouped into phylum platyhelminthes and is acoelomate.
6. (c) Filariform larva of *Ancylostoma* infects a new host (man) by chance contact with his skin.
7. (b) In *Ascaris* first moulting takes place in soil, second in intestine, third and fourth in lungs
12. (a) In *Ascaris* amphids are chemoreceptor which are present on ventrolateral lips.
13. (c) Body cavity of Hookworm is pseudocoelom so it is called pseudocoelomate.

14. (b) *Ascaris* being an endoparasite respire anaerobically because the oxygen content in the hosts intestine is usually poor.
17. (d) The adult *Wuchereria bancrofti* live in lymph vessel and lymph glands. It is a viviparous nematode.
19. (b) *Ascaris* is monogenetic; its infection is through contaminated food and water.
23. (a) The epidermis of *Ascaris* is syncytial (coenocytic) with scattered nuclei and with out partition wall.
24. (d) Male *Ascaris* is differentiable from female *Ascaris* tail end of male *Ascaris* is characterized by the presence of numerous genital papillae on ventral surface. There are 50 pairs of preanal papillae in front of cloaca, and 5 pairs of postanal papillae behind it. Sometimes, two chitinous spiculate process of equal size are seen protruding out of the cloacal aperture. These are called penaeal setae or spicules which serve to transfer sperms into female vagina during copulation.
25. (d) In *Ascaris*, female is with straight posterior end of the body.
27. (c) *Ascaris* is monogenetic parasite; so there is no intermediate host only one host is required for the development.
28. (c) *Ascaris* also secretes anti-enzyme and presence of, cuticle both protect it from hosts digestive enzymes.
30. (c) Ascariasis can be treated by antihelminthic drugs such as Alcopar, Antipar, santonin, chenopodium oil and Tetrachloroethylene etc.
31. (c) *Dracunculus* is digenetic, intermediate host is cyclops or water fleas.
33. (b) Microfilariae are the larva of *Wuchereria* which are carried by *Culex* mosquito.
36. (c) Presence of the resistant thick cuticle is not degenerate but a specialized character with reference to parasitism.
38. (d) The sense organ of *Ascaris* are simple elevations supplied by nerve. They include various papillae, amphids and phasmids.
39. (a) The excretory pore (one) is situated midventrally, a little behind the mouth.
41. (d) Pseudocoelom developes from blastoderm i.e., between mesoderm and endoderm of embryo.
42. (d) Hookworm (*Ancylostoma duodenale*) live in the intestine of man and feed upon blood. No secondary host.
46. (b) Lifespan of *Ascaris* in the host is of 9-12 months.
47. (a) *Ascaris* has three denticulate lips, one median dorsal and two venterolateral.
50. (c) Microfilariae appear in peripheral blood circulation during night while day they disappear.
55. (b) *Wuchereria* is a ovoviviparous parasite which releases numerous juveniles called microfilariae.
56. (b) The embryonated egg passes into the intestine of man and second stage larva hatches out from the egg

## Phylum Annelida

3. (d) Two male genital pores lie ventrolaterally in segment 18.
4. (c) The annelids are triploblastic, i.e., having three germ layers-ectoderm, mesoderm and endoderm.
5. (a) Species of *monocystis* are typically endoparasites of earthworms and occurs in their coelom and seminal vesicles.
6. (a) Pseudocoelom or false coelom is found in nematodes.
8. (b) Both annelids and arthropods possess ventral nerve cord.
14. (c) Typhlosole is a highly glandular, vascular longitudinal ridge increasing the area for absorption of digested food.
15. (c) Botryoidal tissue is found surrounding the alimentary canal of leech and is probably excretory in function.
17. (d) In 4, 5 and 6 segment red colour follicular bodies called blood glands serve for the manufacture of blood corpuscles and haemoglobin.
18. (b) Annelids like oligochaetes exhibit concentric "tube within a tube" body plan with multicellularity and bilateral symmetry.
19. (a) Earthworm is brown or clay coloured. This is because of the pigment porphyrin.
20. (c) Prof. Karm Narayan Bahl of Lucknow University published a memoir on Indian earth worm *Pheretima* in 1926. He was awarded Joy Govind law memorial gold medal in 1942 for notable research in Asiatic Zoology.
22. (b) One pair of ovary and 11 pairs of testis are found in Leech or *Hirudinea*.
24. (a) The *Aphrodite* is a marine polychaete which is commonly called the 'Sea mouse'. It belongs to the phylum Annelida.
29. (a) Clitellar region contains 2000 nephridiopores per segment, so called "forest of nephridia".
30. (c) Coelomic fluid of earthworm contains granulocytes, mucocytes, leucocytes and chloragogen cells.
32. (c) In earthworm, two pairs of genital papillae are situated ventrally on 17<sup>th</sup> and 19<sup>th</sup> segments. It helps in copulation.
33. (b) Flow of blood in dorsal blood vessel of earth worm is from posterior to anterior direction.
35. (c) The single female genital pore is situated in the median position on 14<sup>th</sup> segments.
37. (b) Hearts of *Pheretima* are situated in the segment 7, 9 (Lateral hearts) and 12, 13 (Lateral oesophageal hearts)
38. (d) In earthworm, fertilization is external and occurs in cocoon.
39. (a) During breeding season, glandular cells of clitellum become very active and secrete a slimy substance that forms a girdle like covering around the clitellum. In air, this gradually dries and hardens to form a tough but elastic, ring-like egg capsule or cocoon.
40. (b) Earthworms are monoecious or hermaphrodites but fertilization is crossed type due to protandrous condition.
42. (c) Excretory products of earthworm are urea (about 50%), ammonia (about 40%) and traces of creatinin.
44. (b) In *pheretima posthuma*, the clitellum occurs around the segments 14, 15 and 16.

49. (c) Photoreceptors (with L-shaped lens or optic organelles) of earthworm occurs on dorsal surface of the skin.
52. (b) In each of the segment 7, 9, 12 and 13 is found a pair of large, thick, muscular and rhythmically contractile hearts (Total 4 pairs).
56. (d) In earthworm, blood is red in colour, respiratory pigment haemoglobin is dissolved in the blood plasma.
57. (b) In leech, a triradiate mouth is found at its bottom. The mouth is used for puncturing the skin of the host. It is also suctorial.
58. (a) A larval stage is absent in earthworm, so there is no metamorphosis.
63. (b) The common Indian earthworm is *pheretima posthuma*.
64. (d) Posterior sucker of *Hirudinaria* take part in locomotion and attachment.
67. (b) In earthworm, blood vascular system is different in first 13 segments as regards to number, arrangement and nature of blood vessels.
68. (d) Chloragogen cells are small star shaped, yellow cells concerned with storage of reserve food, deamination of proteins, formation of urea and also excretory.
74. (d) Nephridia are absent in the first three segments and the last segment. Some workers believe that all the nephridia are of micronephridia type. Others consider septal nephridia to be meganephridia.
76. (a) Trochophore larva is present during the development of archiannelida and polychaeta of the phylum annelida.
78. (a) Four pairs of spermatheca are present in earthworm which are situated a pairs in the each 6<sup>th</sup>, 7<sup>th</sup>, 8<sup>th</sup> and 9<sup>th</sup> segments. They open outside on intersegmental groove 5/6, 6/7, 7/8, 8/9.
79. (d) In between the 26<sup>th</sup> segment and the rectum intestine has a median dorsal fold projecting into the lumen. This is known as typhlosole.
80. (a) Roof of pharynx contains pharyngeal glands containing chromophil cells secreting mucus and proteases.
81. (a) Septal nephridia are the only nephridia with nephrostome or funnel.
83. (d) In earthworm, coelomic fluid works as a hydraulic skeleton, aids in locomotion.
86. (b) In earthworm, first segment or peristomium has a ventral mouth with a dorsal lobe or prostomium.
90. (c) Neurons in earthworm are motor, sensory and adjuster (association neurons).
93. (a) In dorsal blood vessel valves are present in front of septum in each segment.
94. (b) Oxygen carrying blood pigment of earthworm is haemoglobin which is dissolved in blood plasma.
98. (d) The coelomic fluid of earthworm is milky white without haemoglobin.
102. (a) Each photoreceptor cell of earthworm has a nucleus and the cytoplasm contains an optic organelle or L-shaped lens or phaosome made up of a hyaline substance.
105. (b) Pharyngeal nephridia of *pheretima* are situated in the segments, 4, 5 and 6. They open in the anterior part of alimentary canal, i.e., buccal cavity and pharynx. They are without nephrostome.
109. (d) Locomotion in earthworm is carried with the help of buccal cavity, setae and the body muscles.

### Phylum Arthropoda

4. (b) Metamorphosis is a conversational process in which small cockroach (nymph) convert into adult due to secretion of juvenile hormone.
5. (c) Insecta is another name of hexapoda, because they have 3 pair jointed legs on thoracic region.
6. (c) Glow-worm and fireflies belong to the insect order coleoptera. *Lampyrus noctiluca* is the common European glow-worm.
9. (a) In cockroach, pigment sheath of ommatidia is non contractile so capable of only apposition or mosaic vision even during night.
10. (c) Presence of jointed legs is unique character of phylum Arthropoda.
14. (a) Arthropoda is largest phylum and includes about 80% of total animals. It includes about 9,00,000 species.
15. (d) Malpighian body is related with kidney of higher chordates animals. It consists of glomerulus and Bowman's capsule.
17. (c) Mandibles are totally absent in the housefly (*Musca*).
22. (b) Terga, sterna and pleura are joined by a flexible arthrodivial membrane.
24. (c) In arachnids, respiration occurs through book lungs which are connected with the outside through spiracles or stigmata.
26. (d) The class insect has largest number of animals. It has about 7,75,000 species.
27. (d) Spider belongs to class arachnida.
30. (d) Most of the economically important species of phylum Arthropoda are found in class Insecta. It includes cockroach, bedbug, termites, silkworm, aphid, rat flea, wasp etc.
36. (d) Haemolymph is found in insect blood which is colourless.
38. (c) In some arthropods like spiders, scorpions, mites, ticks etc., respiration occurs through book lungs or tracheae.
39. (c) The taste receptor (gustatory receptors) are organs of taste, mainly confined to the tips of maxillary palps, labial palps, labium and hypopharynx, in cockroach.
41. (b) *Xenopsylla cheopis*, resembles the human flea and is the chief transmitter of bubonic plague.
42. (c) White ants are found in the tropical and warm temperate countries of the world, white ants are colonial, polymorphic and social insects.
44. (d) Each compound eye of cockroach is composed of 2000 visual units called ommatidia.

45. (a) Malpighian tubules are the excretory organs of insects. It opens at the junction of midgut and hindgut (ileum) in cockroach. Malpighian tubules absorb excretory substances from haemolymph and fat bodies and pass into the proctodaeum.
47. (b) The pupa of mosquito is known as tumbler. It has a life span of 2–7 days.
49. (d) Juvenile hormone is produced by corpora allata in insects. It favours the development of juvenile characteristics. During larval life, this hormone predominates and each moult yields another larger juvenile and keeps the larva in immature condition or maintains juvenility.
52. (b) In cockroach, an elongated, flat phallic gland or conglobate gland on the right side of ventral nerve cord and open out through a small pore close to male gonopore.
54. (c) A larval stage occurs in housefly that lives in dung and is called maggot.
55. (a) In *Pheretima* septa are absent in first four segments and in between 9<sup>th</sup> and 10<sup>th</sup> segment.
58. (d) After completion of metamorphosis housefly and mosquito will transform into an adult called 'Imago'.
59. (a) The mosquito (*Culex*, *Anopheles*, and *Aedes*) are pathogenic. The fleas (*Culex*) is also pathogen i.e., ectoparasites of birds and mammals, feeding on blood and the tse-tse fly is pathogen for sleeping sickness.
61. (a) Moulting is controlled by a steroid hormone ecdysone produced by prothoracic glands.
62. (c) Cockroach is omnivorous, feeds on all sorts organic debris.
63. (a) Johnston's organ lies in the second segment of antennae. In male mosquito, it helps to locate females by flight tone.
65. (b) In mosquito and housefly, halteres develop from metathorax. They are balancing organs during flight and also receive sound stimuli.
69. (a) In cockroach, a pair of many jointed structures are present on the tergite of 10<sup>th</sup> segment in both sexes, called anal cerci.
70. (b) In mosquito, 5<sup>th</sup> instar larva changes into a pupa (nonfeeding), it is comma-shaped.
71. (c) Different stages in the life history of housefly are – Egg – Larva (Maggot) – pupa – Imago (adult).
73. (d) Corpora allata is attached to the brain. It secretes juvenile hormone (Prolongs larval period).
74. (a) Cockroach is unisexual and exhibit sexual dimorphism. In male's ninth segment bears a pair of anal styles ventrally.
75. (d) Metamorphosis in cockroach is incomplete or paurometabolous type. Incomplete metamorphosis is also called gradual metamorphosis.
76. (d) If food material of housefly is solid, such as a sugar crystal, the fly first pours a little saliva or regurgitates droplets of liquid from its crop to liquify it and then sucks the liquid which fills the tubular pseudo-tracheae by capillary action.
77. (c) Metamorphosis of insects is controlled by a steroid hormone ecdysone produced by pro-thoracic.
79. (b) The total number of ganglia in ventral nerve cord of cockroach is nine pairs, i.e. three pairs thoracic and six pairs abdominal.
80. (d) In male *Anopheles*, mandibles are totally absent because it is fed on nectar and have only sucking mouth parts.
84. (c) The major excretory product of insects is uric acid, so they are uricotelic.
88. (c) *Anopheles* shows sexual dimorphism. Sex differentiation can be done on the basis of antennae and maxillary palps.
89. (b) In cockroach, the trachea is lined with spiral thickening of cuticle called intima which prevents the tracheal tubes from collapsing (Trachea of rabbits is also non collapsible).
92. (a) Cockroach has two pairs of wings. The first pair (mesothoracic) are thick, hard and leathery, protective in function called tegmina or elytra second pair (metathoracic) are thin, soft and membranous.
95. (d) Bed bug, sand fly, silk worm are placed in tracheate group of Arthropoda because they have tracheae for respiration. Embryonic development of echinoderms shows a number of similarities with those of chordates.
97. (b) In female cockroach, abdomen is broader than in male.
98. (d) All body tissue receive oxygen directly through tracheoles.
100. (a) In *periplaneta*, wings are well developed and in female of *Blatta*, the tegmina are very short, hind wing absent.
101. (a) The heart of cockroach is formed of 13 chambers each chamber (except the last one) has a pair of small lateral apertures called ostia which open into the pericardial sinus.
102. (d) Haploid parthenogenesis is called arrhenotoky. In it, development of egg into adult organism without fertilization. Example Honey bees, wasps and ants.
104. (c) The longest podomere or segment of cockroach is tibia.
106. (b) Housefly and butterfly possess larval stage. Their larval forms are maggot and caterpillar respectively.
107. (b) In butterfly, proboscis is long and is formed by galea of maxillae.
110. (c) Locusts are herbivorous in diet and gregarious in nature, migrating or swarming in great number.
112. (a) The labellae are traversed by a series of channels known pseudobracheae, because of their resemblance once to tracheae in appearance.
113. (b) In cockroach, the tracheal system opens outside by ten pairs of spiracles. The first and third pairs spiracles remain open all the times.
114. (a) In insects, juvenile hormone or neotinin is produced by the corpora allata. It favours the development of juvenile characteristics. During larval life, this hormone predominates and each moult yields another larger juvenile.
116. (d) Antennae of cockroach bear tactile and olfactory receptors and are sensitive to touch and smell.
119. (c) Spider bears spinnerets or spinning organ just anterior to the terminal anus. These produce silken threads for construction of spider-web.

122. (b) Ootheca of cockroach contains sixteen fertilized egg in two rows.
123. (c) Ootheca of cockroach is formed of a protein secreted by collateral gland.
125. (b) Palaemon is commonly called as prawn. It is an aquatic animal. It belongs to class crustacea of the phylum arthropoda.
127. (b) Sexual dimorphism is found in both *Ascaris* and cockroach.
128. (a) White ants are social and polymorphic insects, living in large, well organised colonies.
133. (a) Holometabolous or complete metamorphosis, includes four developmental stages – egg, larva, pupa and adult. Example – Lady Bird beetle (*coccinella*).
134. (c) Malpighian tubules of cockroach are concerned with homeostasis, osmoregulation and excretion. These are between 60 to 150 in number and are arranged in 6 – 8 bundles
135. (b) Nephridia are absent in arthropoda.
136. (b) *Peripatus* belong to onychophora. In *peripatus*, excretory organs are nephridia.
137. (b) In case of gradual metamorphosis, the newly hatched creature resembles an adult in general body form, but lacks wings and external genital appendages. It is also called paurometabolous development.
139. (b) Caterpillar of *bombyx mori* after 4 or 5 days, stops feeding and become inactive; Moulting or ecdysis then taken place. The larva repeats this process four times
142. (a) Crustacean are the dominant arthropods of sea, with cephalothorax, biramous appendages, and respiration by gills. Common example are prawn, lobsters and crabs.
143. (d) *Limulus* or king crab belong to the sub class xiphosura and class merostomata of sub phylum chelicerata of phylum arthropoda. It is a living member of very ancient primitive chelicerates and hence called a "living fossil."
144. (c) Silver fish (*Leptisma*) is a primitive wingless insect without metamorphosis. It belongs to the phylum arthropoda.
145. (a) Caterpillar and maggot are the larva of respectively butterfly and housefly.
147. (b) Mouth parts of housefly are sponging type. These are adapted for sucking liquid or semiliquid.
148. (c) Tornaria larva is larva of *Balanoglossus*
150. (b) The larva of mosquito is also known as 'wiggler'.
151. (d) The amount of yolk determine the type of cleavage in the egg. In superficial meroblastic cleavage, the cleavage remains restricted to the peripheral portion of the egg. This cleavage occur in arthropods especially insects.
153. (b) Exoskeleton of arthropod is light weight, tough and composed of structural polysaccharide chitin
155. (b) In earthworm as well as cockroach, a ventral nerve cord extends back along the midventral axis from the sub pharyngeal ganglion.
157. (c) Abductor and adductor muscles associated with the mandibles move these in horizontal plane to cut and chew the food particles that are brought in between the mandibles by the first maxillae.
161. (a) In cockroach the food is grinded by mandibles and gizzard. In insects there is no oxygen transporting pigment and nitrogenous excretory product is uric acid.
162. (c) Cray fish (*Astacus*) is the phylum arthropoda.
163. (c) Leg of cockroach is five segmented, segments from base are-coxa, trochanter, femur, tibia and tarsus.
164. (c) In mosquito, metathoracic or hind wings are modified into halteres which are balancing and sound producing structures.
167. (b) Arthropoda have a compound eyes. Each compound eye is made of a large number of independent visual elements, called ommatidia. It helps in photoreception.
168. (a) The mouth parts of male mosquito are of sucking type while those of female mosquitoes are of piercing and sucking type.
169. (d) In cockroach, pigment sheath of ommatidia is non contractile so capable of only mosaic vision even during night.
170. (c) *Musca domestica* shows a complete metamorphosis (holometabolous type).
171. (d) Haemocoel is the body cavity of arthropods and molluscs, containing blood.
- 174 (a) Scorpion and ticks belong to the class arachnida of the phylum arthropoda.
181. (a) Pheromones are the secretion of small amount of chemical substance leading to specific physiological or behaviour responses in other members of the same species. Pheromones are also used to induce mating.
183. (b) In cockroach, newly hatched young one is called nymph. It resembles the adult in general structure but lacks the wings and mature reproductive organs.
195. (b) Class crustacea includes cyclops other options are from class insecta.

### Phylum-Mollusca

4. (c) In *septa*, the foot is modified into oral arms and siphon.
6. (a) Dentalium is commonly known as 'elephant's tusk-shell'.
7. (a) In bivalve molluscs (*Unio*) the gills are formed by fusion of successive branchial or gill filaments. These are surfaced with cilia. The beating of lateral cilia of gill filaments draw water into the infra branchial chamber of mantle cavity through the incurrent siphon. The water contain food material of *Unio*.
8. (d) Decapoda is not a class of phylum mollusca. It is order of phylum Arthropoda.
11. (c) Sea hare (*Aplysia punctata*) and snail (*Helix*) belong to same class gastropoda of phylum mollusca.
12. (c) Twisting of visceral mass in the snails through an angle of 180° due to which snails become asymmetrical.



13. (c) *Neopilina* is a most primitive mollusca having characters of annelida i.e., internal metameric segmentation, 5 pair of nephridia etc. There is no common name of this mollusc which is truly a living fossils and connecting link between annelids and molluscs.
17. (b) Cephalopoda word is composed of two words *cephalo* and *poda* which in Greek language means head and foot respectively i.e. foot present on head.
18. (d) The head of snail bears a pair of short, fleshy and stump-like optic stalk or ommatophores, one on either side behind 2<sup>nd</sup> pair of tentacles each ommatophore bears a small, black and some what circular eye, slightly below its tip on the other side.
19. (c) Mantle secretes a calcareous shell which is generally external but may be internal an supportive or absent.
20. (c) Snail moves with the creeping activity of the muscular sole of its foot.
22. (c) *Octopus* belong to the class cephalopoda of phylum mollusca.
25. (a) Mantle, foot and shell are characterstics of a mollusc. Out of the given options *Nautilus* is a mollusc, It is a tetrabranch cephalopod.
28. (a) *Loligo* is a commonly known as "cuttle-fish". It is belong to phylum mollusca.
29. (b) *Teredo* is commonly known as 'shipworm'. It is a highly specialized marine bivalve which is very destructive to wood in sea water. The body is long and slender with a small anterior shell. The shell is used for burrowing in the wood of ships or wharves.
30. (a) Radula is found in gastropods.
31. (c) In mollusca, blood has amoebocytes and often a copper containing blue respiratory pigment called haemocyanin.
32. (b) *Unio* display filter-feeding that involves straining food from large quantities of water.
35. (b) Snail may tide over long periods of drought by remaining torpid with the shell aperture tightly closed. It is then said to be in summer sleep or aestivation.
36. (d) *Octopus* belongs to the class cephalopoda of phylum Mollusca.
37. (c) In mollusca, excretion occurs through paired sac like kidneys (or metanephridia) but in echinodermata kidneys are absent and excretion occurs partly by diffusion through body surface and partly by amoeboid coelomocytes.
39. (a) Shell is internal *septa*, *Loligo*.
41. (b) Ammonites belong to subclass ammonioidea of class cephalopoda. It is the largest subclass of extinct mesozoic cephalopods.
42. (d) Scaphopoda commonly called tusk shell, body within a tubular shell open at both ends.
4. (d) Pedicellariae of *Asterias* are minute, whitish jaw like structure, found on both the body surface, in association with spine. It's help in the capture of prey and removal of debris.
5. (c) The members of class crinoidea, are commonly called feather star or sea lilies because of their lily flower like appearance.
9. (c) Star fish belong to class Asteroidea of phylum echinodermata.
10. (b) In class ophiuroidea, Ambulacral grooves are absent or covered by ossicles.
12. (b) When irritated or when subjected to unfavorable conditions, many species of sea cucumbers cast out a part of their viscera by a strong muscular contraction that may either rupture the body wall or evert its contents through the anus or sometime mouth. The lost part regenerate again.
14. (c) Echinoderms are exclusively marine most members are bottom dwellers or bathyonic some are pelagic while a few are sedentary.
16. (c) Adult echinodermata (Star fish) show pentamerouradial symmetry while larvae are show bilateral symmetry.
23. (d) Cephalization is a process of Brain formation. In echinodermata brain is absent, nervous system is consist only nerve ring and radial nerve cords.
24. (d) Sea squid (*Loligo*) belong to class cephalopoda of phylum mollusca.
27. (a) Echinoderms are true enterocoellic animals, which is formed from enteron of gastrula like chordata.
28. (c) Tube feet act as locomotory organ in star fish.
30. (a) Antedon belong to class crinoidea of phylum echinodermata. It is a living fossil and commonly known as feather star
31. (a) *Gorgonocephalus* (Basket-star) belong to ophiuroidea. The body of *Gorgonocephalus* is consist of large pentagonal disc and five elongated and much branched arms.
33. (d) Sea lilies are member of crinoidea having long stalk
35. (d) Sea lily belong to class crinoidea of phylum echinodermata. Echinoderms possess both exoskeleton and endoskeleton. The endoskeleton consist of calcareous plates or ossicles while exoskeleton consist of spines and pedicellariae.

### Phylum-Chordata

1. (d) Aristotle's lantern is a five teeth masticatory apparatus which is present surrounding to the mouth. It is used by sea urchin for feeding. Presence of Aristotle's lantern is characteristic of class Echinoidea
3. (d) The larva (tadpole) undergo retrogressive metamorphosis i.e., change from better developed larva to less developed adult e.g., *Herdmania*. The notochord is only present in the tail of larva and disappear in adult.
5. (b) On the basis of presence or absence of jaw subphylum vertebrate is classified into Agnathostomata and Gnathostomata. In gnathostomata all that animals are included in which jaw is present.
6. (c) In poikilothermal (cold blooded) animals, body temperature varies according to the temperature of the environment.



7. (b) *Amphioxus* (*Branchiostoma*) is placed in subphylum cephalopoda, in which notochord is present throughout life along entire length of the body.
9. (a) The blood vascular system in hemichordates is simple and open type. It includes a dorsal heart and two longitudinal vessels (one dorsal and one ventral). In chordates, closed circulatory system is found except in hemichordata or stomochordata (e.g., *Herdmania*) where, open circulatory system occurs.
11. (c) This type of metamorphosis shows retrogression or degeneration from larva to adult.
12. (b) Both are included in class cyclostomata.
16. (d) Homeothermic or warm blooded animals are able to maintain constant body temperature. e.g. Aves and Mammals.
22. (c) A post anal tail occurs in most chordates atleast in embryonic stage. In majority of the chordates it helps in balancing. Tail provides protection to genital and anal regions.
24. (d) Crocodile, Penguin, Whale and Dogfish all are chordates. So, all have gill slits at some stage of development.
25. (b) In cyclostomata, body is eel shaped with scales jaw and lateral fins. Mouth rounded and suctorial. e.g. *Petromyzon* and *myxine*.
32. (a) In vertebrata, notochord is replaced partly or fully by a jointed vertebral column (back bone) i.e. vertebral column is derived from notochord.
34. (b) Presence of well developed skull or cranium is important diagnostic feature of chordata.
37. (c) Ostracoderms are earliest known primitive fish like extinct vertebrate. These along with cyclostomes constitute the Agnatha.
40. (c) Homeothermous animals are also known as warmblooded or endothermal animals. With constant body temperature, body heat is produced by the metabolic reaction taking place within the body. e.g. Aves and mammals.
41. (a) In fishes and amphibian, amnion is absent and called Anamniota.
42. (c) In urochordata, notochord and nerve cord is found only tail region in tadpole like larva.
45. (c) Notochord is the prime diagnostic feature of phylum chordata. Chordates possess notochord either throughout whole life or during early embryonic period.
48. (c) Tunicates are ciliary or filter feeder animals, which obtain their food from diatoms, desmids, protozoans and others pelagic microscopic organism, suspended in sea water, by the ciliary movement of wheel organ.
2. (b) *Elasmobranchii* (dog fish) is an alternative name for cartilaginous fish or chondrichthyes. The name refers to the fact that the gill-slits are exposed and not covered by an operculum.
4. (d) *Torpedo* (*Astrope*) is the electric ray. Their electric organs are highly modified masses of muscles cells
6. (d) *Protopterus* is the member of Dipnoi, which shows double breathing through gills as well as lungs.
8. (a) Cyclostomes lack paired appendages. Aves have dry skin, without glands, only preen gland at base of tail present. Whale lack body hairs and hind limbs.
13. (d) Sea horse (*Hippocampus*) has bony plates/scutes in addition to scales.
16. (a) Silver fish (*Lepisma*) is an arthropod.
17. (a) Dog fish or scoliodon is a true fish whereas silver fish, star fish and whale are arthropod, echinoderm, and mammal respectively. Catfish is a true fish. It has sensory barbels without scales.
19. (b) One auricle and one ventricle.
20. (c) Sea horse (*Hippocampus*) belongs to the class osteichthyes (due to bony skeleton) of super class pisces.
21. (b) Pisces, amphibia and reptiles are unable to maintain constant body temperature hence, called poikilothermic or cold blooded animal.
22. (b) Fishes have two chambered heart one auricle and one ventricle, which receive only venous blood and pump it to gills for purification.
23. (a) Sea horse or hippocampus is a fish.
30. (b) *Wallago attu* is commonly known as catfish. It possess very small eyes and well developed sensory barbels by which they make a good vision and find their way.
33. (b) *Hemicyclaspis* is a genus of fossil, primitive, jawless fish like animals belonging to the class ostracodermi.
34. (b) Sucker fish attached to shark, feeds on the left over of shark's prey. The relationship is that of commensalism or ectocommensalism.
35. (d) Whale-mammals, cuttlefish-cephalopod and silver fish-insect.
36. (a) Anadromous fishes move from sea to fresh water for breeding e.g. salmon.
39. (a) *Anguilla* is commonly known as freshwater eel. Eel is the name for a number of smooth snake like fishes with continuous dorsal anal and tail fins and without pelvic fins. *Anguilla anguilla* the European eel is born in the Sargasso sea.
41. (b) *Echeneis* is commonly known as sucker fish. Its upper surface bears a large, flat oval adhesive disc or sucker. Sucker represents modified anterior dorsal fin.
42. (a) Claspers are intromittent organs found on the pelvic fins of male cartilaginous fishes like sharks. Sphyrna is commonly known as 'hammer-headed shark'.
47. (c) Lateral line system in a fish and some aquatic larvae (Tadpole) is made up of neuromast organs. It detects vibrations and pressure changes in water.
48. (c) *Latimeria* is called living fossil as it has remained unchanged for several million years.
50. (a) Cartilaginous fishes belong to the class chondrichthyes due to cartilaginous endoskeleton of superclass pisces.

### Class-Pisces

1. (a) Lateral line system is found in fishes. It serves to detect waves in water current, thereby helps in swimming process by perceiving the distance of surrounding objects.

51. (c) *Anguilla* sp (Eel) is a catadromous fish that lives in fresh water and breeds in sea.
53. (d) All chondrichthyes possess cartilaginous endoskeleton without exception.
54. (a) In class chondrichthyes males possess claspers on the plevic fins.
61. (a) Mackerel is a marine fish having rich source of omega-3 fatty acids

### Class-Amphibia

4. (b) Tortoise is a reptile belonging to the order chelonia
5. (d) Mud puppy is an aquatic salamander of genus *Necturus* with persistant gills. It is found in North America.
6. (b) Salamander is a semiterrestrial lizard-like tailed carnivorous and nocturnal amphibian.
8. (c) *Ichthyophis* is a limbless amphibian of 15-22 cm length that lives in burrows in moist soil.
9. (a) Ability to change colour as in amphibians by expansion and contraction of pigment cells is called metachrosis.
10. (a) *Rhacophorus* has characteristic large webs developed between the much elongated digits. Webs and flattened body serve as a parachute in gliding from higher elevation to a lower ones, so they are designated 'flying frogs'.
11. (c) *Hyla* is also known as tree frog.
12. (a) The functional kidney of a frog tadpole is pronephros (head kidney) developed from nephrostomes in the anterior region.
13. (c) Environmental factors affect metamorphosis in several ways. Abundance of food, cold temperature or insufficient iodine (component of thyroxin hormone) may cause failure of metamorphosis and retention of larval features.  
Calcium, magnesium, phosphorus are not found to play any role in metamorphosis in animals. Larva of *Ambystoma* is known as axolotl. It is found in USA (North America) and Maxico. It show neoteny or paedogenesis.
14. (b) *Ichthyophis* is a limbless amphibian showing parental care. It has no tongue.
16. (a) *Pipa americana* is commonly known as surinam toad.
17. (d) Caecilians or limbless amphibians belong to the order Gymnophiona or Apoda. They are sometimes called blindworms.
18. (d) *Bombinator* is a small sized amphibian found in Europe. It is commonly known as Fire-bellied toad
25. (c) Frog is ureotelic because nitrogenous excretory product is usually urea.
3. (b) *Heloderma* (Gila monster) is the only poisonous lizard in the world. It is also called 'Beaded lizard' because its scales resemble beads.
7. (c) Reptiles have body temperature which varies with that of its surroundings and embryos have amnion, chorion and allantois.
9. (d) Body of Tortoise is enclosed in two shell plates, dorsal carapace and ventral plastron.
11. (a) Cobra is characterized by hood supported by ribs bearing spectacle mark dorsally. The third supralabial shield of upper lip touches eye and nasal shield.
13. (c) Poison glands of snake are modified salivary glands (Superior labial or parotid glands)
14. (b) A snake has no middle ear. It perceives sound through skin from earth.
16. (b) Colour changing power is present in pisces, amphibians and reptiles but absent in aves and mammals.
18. (a) In scorpion and spiders the respiratory organs are book lungs. They are named so because their folds resemble the leaves in a book. In this the exchange of gases takes place between the air of interlamellar spaces and the venous blood through the thin membranous walls of the lamellae.
20. (a) The tail of most lizard is easily broken off when threatened or seized by a predator. This ability is known as autotomy. Autotomy is voluntary breaking tail to confuse enemy.
24. (d) In poisonous snakes, two maxillary teeth are enlarged, grooved or tubular. They are called poison fangs and are concerned with injecting poison.
25. (a) *Draco* is a lizard which glides with the help of patagium, it is called 'flying dragon'.
27. (a) Two common marine poisonous snakes are *Enhydryna* and *Hydrophis*.
28. (c) Snakes shed scaly epidermis of skin periodically usually in one piece. This process is termed moulting of ecdysis of cornified cells of skin.
29. (b) A viper can be easily identified by its triangular, pearshaped head bearing small cephalic scales.
31. (a) Gavial or gharial, *Gavialis gangeticus* is found in freshwater. It lives in Gangas and Brahmaputra rivers and grows to 8 metres.
36. (b) The lung cavity of crocodile is separated from rest of the body cavity by a muscular diaphragm.
39. (b) There are two species of *Heloderma*, *H. Suspectum* and *H. horridum*. Both are found in America.
41. (c) Shelled eggs are found in reptiles and birds are known as cleidoic eggs.
43. (b) *Calotes versicolor* is commonly known as Garden lizard. It is quite common in hedges, garden and jungles.
45. (b) Foramen of panizae is a aperture in the heart of lizards and crocodiles. It is located at the point where right and left aortae cross each other and are in contact
49. (a) *Python* and *Boa* have vestigial pelvic girdle and hind limbs.
50. (d) In some reptiles, cloacle aperture is transverse and male is without copulatory sacs (Penis) e.g. *sphenodon*. They are includes in order Rhynchocephalia.

### Class-Reptilia

1. (c) Classification of reptiles is based on temporal fossa (vacuties) on skull.
2. (a) Typhlopidae includes burrowing snakes having a vestigial pelvic girdle and having reduced eyes covered by scales; found in almost all parts of the world except New Zealand.

51. (c) Eyelids of snake are immovable, nictitating membrane is absent.
52. (b) The loss of water from body is prevented by dry cornified scales on the body of reptiles. It is a favourable land adaptation.
55. (c) In India, antivenin injections are prepared at Haffkin's Institute, Mumbai and Central Research Institute, Kasauli (Shimla).
56. (b) Poison of cobra is most virulent. It is a neurotoxin attacking nerve centres and causing paralysis of muscles, especially those of respiratory muscles.
58. (d) Crocodile is a carnivorous and feeds on fish, aquatic birds and mammals. It has thecodont teeth.

### Class-Aves

2. (c) Coverts are small feathers similar to quills meant for filling gaps on the wings and tail.
3. (a) A synsacrum is formed by fusion of posterior thoracic, lumbar, sacral and anterior caudal vertebrae.
4. (d) Penguin is a flightless bird occurs in flocks in the Antarctic region and some islands of south Africa.
5. (a) The flightless bird cassowary occurs in N.E. Australia and New Guinea.
10. (c) Presence of a single functional ovary of the left side in the female bird leads to reduction of weight which is so essential for flight.
11. (a) Ratitae are the flightless birds which are grouped under super order paleognathae.
15. (c) Archaeopteryx possessed prolonged jaws or beak. However, it contained teeth.
17. (a) Heterocoelous is a term used to denote a vertebra whose centrum has one face convex and the other concave.
19. (a) The syrinx or sound producing organ lies at or near the junction of trachea and bronchi.
20. (a) Huxley has called birds to be glorified reptiles.
25. (b) Birds are homeothermic or capable of keeping their body temperature constant.
27. (b) Pigeon are noted for their unique ability to produce 'pigeon milk' by crop glands. It is formed by the degeneration of the epithelial cells lining the crop. The milk is produced by both sexes.
29. (b) The clavicle and interclavicles are fused to form a V-shaped bone, called furcula or wishbone or merry thought bone which help in flying.
30. (d) Birds have bipedal locomotion because fore limbs are modified into wings.
31. (d) Egg of ostrich weighs nearly 1.5 Kg. and requires about 50 minutes to boil it. It is the largest egg among the animals.
32. (c) Bones of birds are pneumatic or hollow and have no bone marrow.
33. (b) In birds, only one gland is present in the skin at the base of short tail or uropygium. It is known as oil or preen gland.
37. (c) Kiwi is the smallest living flightless bird. It is found in New Zealand.

### Class-Mammalia

4. (b) Prototherians are primitive, egg laying mammals, oviparous mammals, reptile like mammals, confined to Australian region.
5. (d) Most important character of mammals is the presence of mammary gland and internal fertilization.
6. (a) *Manis* (Pangolin or scaly anteater) belong to the order pholidota of the class mammalia.
8. (b) Eutheria includes viviparous placental mammals.
11. (a) Animals belonging to the order rodentia have each jaw with one pair of long rootless chisel-like incisors growing throughout life.
13. (d) Mucous makes skin moist. Moist skin is helpful in respiration.
17. (b) Rabbit belongs to the order lagomorpha of the class mammalia.
19. (a) *Didelphis* (opossum) is a tree dwelling which is found in America. It belongs to the metatheria.
20. (b) Monotremes is a group showing peculiar characteristics as a mixture of reptilian and mammalian features.
21. (b) Kangaroo (*Macropus*) found in Australian region which belongs to the order marsupialia or metatheria.
31. (d) Most unique character of mammalian brain is presence of corpus callosum. It connects the two cerebral hemispheres internally.
34. (b) The zoological name of common north Indian hare is *Lepus ruficaudatus*.
36. (c) Double vagina is main character of marsupialia.
40. (c) Except a few, only mammals possess seven cervical (neck) vertebrae.
42. (c) Ungulata comprises large sized hoofed mammals such as pig, horse, ass, camel, deer, sheep, goat, cow, buffalo etc. These animals are domesticated by man for centuries.
49. (c) The adaptations in desert lizard are  
(i) Burrowing in soil to escape high temperature  
(ii) Bask in sun when temperature is low
50. (d) Head louse living on the human scalp as well as laying eggs on human hair is a parasite in true sense. Female mosquito is not considered as a parasite, though it needs human blood for reproduction. Koel that lays in crow's nest is just a brood parasite.
51. (b) The zoological name of tiger is *Panthera tigris* in which *Panthera* is genus and *tigris* is species.
53. (c) 3-chambered heart is found in only members of class Amphibia and Reptilia.
54. (b) Diaphragm is commonly found in only mammals (kangaroo) except crocodile.
58. (d) Sea lion (*Zalophus*) is a large-eared seal. It belongs to the order carnivora.
62. (d) In male platypus a grooved erectile poison spine is present on the tarsus which is served by a poison gland in the thigh. The poison is used to immobilize a female during coition.
64. (d) In whale, Retea mirabilia are present which store extra oxygen and help the animal to remain under water for some time.

69. (d) Brain of prototherian relatively small, simple and without corpus callosum.
73. (a) In prototherian, mammary glands are modified sudorific glands and they lack the nipples or teats.
75. (c) Marsupium or marsupial pouch is the main characteristic of metatherian (mammals).
76. (d) *Echidna* (*Tachyglossus*) is found in Australia, New Guinea and Tasmania.
77. (b) Members of order Monotremata of sub class prototheria are oviparous. i.e. egg laying mammals. e.g. *Echidna* (*Tachyglossus*), *Ornitho-rhynchus* (Duck billed platypus).
78. (c) Order Primata includes lemurs, lorises, tarsiers, monkeys, apes and man.
79. (a) Order Insectivora comes under sub class Theria of class Mammalia.
30. (b) Two type of air bladders are known. In the more generalized groups of teleosts, the air bladder retains connection with the gut via a pneumatic duct, just as in ganoids and dipnoi. Such an open air bladder is called physostomous. In the teleost *Erythrinus* the air bladder has a lateral attachment to gut. Such a closed or ductless air bladder is called physoclistous.
31. (b) Catla, Labeo and cirrhinus are fresh water fishes. These are important culturable species in India.
32. (a) Enterocoelic coelom is found in echinoderm to chordates.
34. (b) Python captures its prey and directly engulfs it by creating suction pressure inside its mouth.
35. (b) Ophisaurus is a limbless lizard also known as glass snake.

### Critical Thinking Questions

2. (b) *Trichinella spiralis* shows viviparity.
6. (a) Nutritive muscular cells bear both flagella and pseudopodia.
7. (b) Trichocysts of *Paramecium* and nematocysts of *Hydra* are the organ cells of offence and defence.
8. (b) In *Hydra*, undigested residues are egested from coelenteron through mouth and body wall.
10. (a) *Taenia saginata* is also 'unarmed tapeworm' because the scolex does not possess hooks.
14. (d) Dorsal blood vessel is collecting blood vessel in the segments 14 onwards and distributing blood vessel in segments 1 to 13.
15. (a) Blood glands of *Pheretima* serve for the manufacture of blood corpuscles and haemoglobin.
17. (c) Weberian ossicles refer to a paired chain of three or four small bones in certain fishes e.g. Carps and cat fishes. It connects the air bladder with auditory capsule.
19. (b) Presence of notochord, Dorsal tubular nerve cord, Pharyngeal gill clefts, post anal tail, RBCs and hepatic portal system is distinguishing feature of chordates.
21. (a) Crocodile is an exceptional case of reptile having 4 chamber in heart while other reptile shows 3 or 3½ chambered heart.
23. (d) All these (coelacanth, limulus and sphenodon) are representative of its own kind hence called living fossil.
24. (d) The characteristic feature of amniota is the development of amnion and other foetal membranes during development. Amnion and other foetal membranes are developed in reptiles, birds and mammals.
25. (b) Tunicates (*Herdmania*) shows retrogressive metamorphosis which results in the degeneration in adult.
28. (a) In mostly cartilaginous fishes caudal fins (Tail fins) forms two unequal lobe, which act as steering organ in locomotion.
29. (c) Stenohaline fishes have only a narrow range of salinity tolerance and hence remain restricted to either fresh or salt water.
36. (a) Pisces and amphibia are anamniotic while reptiles, aves and mammals are amniotic.
37. (a) Anapsida has a solid roof due to the absence of any temporal vacuities on skull.
39. (b) All flightless birds belong to the super order Ratitae e.g. Emu, Penguin, Rhea, Kiwi, Moa, Cassowary.
40. (d) The presence of seven cervical vertebrae is common feature of mammals.
45. (d) Sea cows (*Rhytina*) belong to order Sirenia of mammals. Presence of blubber and few hairs are characters of order sirenia.
46. (c) Silver fish belong to Insecta in which respiratory organ is tracheae, scorpion belong to Arachnida which respiratory organ is book lung sea squirt (*Herdmania*) belong to urochordata, which respiratory organ is pharyngeal gills.
47. (c) Sponges "multicellular grade" organism but exhibit cellular level of organization.
48. (c) Embryonated eggs → Mouth → Intestine → Liver → (2<sup>nd</sup> stage larva)  
Heart → Lungs → trachea → Pharynx → Intestine.  
(4<sup>th</sup> Stage larva)
49. (d) Cockroach and earthworm have common type of spermatheca. The spermathecae receive and store sperm cells during copulation.
50. (a) Earthworm is a bisexual or hermaphrodite but always shows cross-fertilization due to protandrous conditions.
54. (a) Reptiles, aves and mammals are amniotes while amphibia is an anamniote.
55. (a) Bioluminescence is a method of light producing by living organisms in which usually certain protein called luciferins in the presence of oxygen and an enzyme luciferase, are converted to oxyluciferins with the liberation of light.
56. (b) In some gymnophiona, dermal scales are embedded in dermis. Skin shows transverse wrinkles.
57. (a) Pseudocoelom formed by blastocoel surrounds the alimentary canal in Nematodes (*Ascaris*).
59. (c) *Salamandra* is a tailed amphibian, has tympanum which represents ear.

60. (b) Circadian rhythm or diurnal rhythm is any 24 hour periodicity in the behaviour or physiology of animals or plants. Examples are the sleep/activity cycle in many animals and the growth movements of plants. Circadian rhythms are generally controlled by biological clocks
64. (a) Although the *Amoeba* has no sense organs, it responds to chemical stimuli. It makes this determination by chemotaxis, a kind of chemical sense. This is the same response mechanism that our white blood use when they encounter and phagocytize a pathogen.
73. (b) Members of *ctenophora*, *cephalochordate* and *echinodermata* are exclusively marine.
74. (b) A – Insects  
B – Molluscs  
C – Crustaceans  
D – Other animal groups.
75. (b) Exoskeleton is mainly responsible for diversification of insects on land

### Assertion and Reason

1. (e) Sponges are the lowest multicellular animal but they have simple structures. Organs and tissues are absent. The constitution cells perform their functions more or less independently exhibiting division of labour performing specialized functions. Hence, they possess cellular level of organization.
2. (d) In Mollusca, circulatory system is of open type with a heart made up of two auricles and a ventricle. The blood has haemocyanin.
3. (a) *Leucosolenia* shows simplest (ascon) type of canal system. In this, surrounding water enter the canal system through ostia. This water of sea enters into the spongocoel and pushed out readily through osculum. Course taken by the water current in the body of sponge may be shown as under
- Ingressing  $\xrightarrow[\text{Ostia}]{\text{Through}}$  Spongocoel  $\xrightarrow[\text{Osculum}]{\text{Through}}$  To outside
4. (e) Robert Grant (1857) was the first to recognise and prove the true animal nature of sponges. The animal nature of sponges was well established on the following grounds-
- (i) Sponges feed on inwafted solid particles. Their mode of nutrition is truly holozoic.
- (ii) Sponge cells are devoid of cellulose cell walls.
- (iii) Life cycle of sponges include swimming ciliated larval stages resembling those of other marine animals. Sponges are sessile and digestion is very simple without any apparent way of capturing food or eliminating wastes.
5. (a) The duck billed platypus and the spiny anteater are primitive oviparous, reptiles like mammals and these are included in subclass prototheria of class mammalia. Both of them have 12 pairs of cranial nerves and 7 pairs of cervical nerves
6. (b) Tape worm belonging to phylum platyhelminthes, pinworms and roundworm belonging to phylum nematoda, are all endoparasites. They all are intestinal parasites. In case of *Taenia solium* man gets infection by uncooked or improperly cooked measly pork. *Cysticercus* becomes active on reaching the intestine. *Proscotex* everts or evaginates in the intestinal wall. *Ascaris*, being an endoparasite inhabits the small intestine of man, more frequently of children than of adults. Man gets infection by consuming contaminated or uncooked food and water. *Enterobius vermicularis* or pinworm live in caecum, appendix and at the junction of large and small intestine. They are also transmitted in the same way like *Taenia* and *Ascaris*.
7. (c) Coelenterata is the phylum of acoelomate and radially symmetrical lower invertebrates. Due to their radial body symmetry they are also known as radiata. Bilateral symmetry starts from the phylum platyhelminthes.
8. (c) *H. viridis* is green in colour. Its bright green colour is not because of chlorophyll containing chloroplasts, but due to the presence of symbiotic zoochlorellae, *Chlorella vulgaris*, a unicellular green alga, that lives in its gastrodermal cells.
9. (a) Coelenterates possess a very primitive type of nervous system. This system is composed of many nerve cells. In coelenterates, the separate mechanisms for digestion, respiration and excretion, reproduction etc evolved for the first time. Thus there is a constant need to maintain coordination between these systems. Nerve cells are developed for this purpose, for the first time in coelenterates. Nerve in *Hydra* is the beginning in the evolution for nervous system.
10. (b) Realm is a large landscape (generally subcontinental) having its unique biodiversity. South Asia (including India) occurs in oriental realm; king cobra is endemic here and kangaroo is found in Australian realm. Wallace line is the imaginary line separating oriental and Australian realms.
11. (b) Bats and whales are the members of class Mammalia (*L. Mamma* = breast). The bats are the only mammals which have wings can really fly while whales are the largest animals in existence. Both bats and whales have four chambered heart but birds and crocodiles also have four chambered heart.
12. (b) The birds are the most beautiful among the animals. They show court ship, nest building, parental care, migration and territorial behaviour. Koel (*Eudynamis*) does not make any nest but lays eggs in the crow nest. In this way koel is nest parasite.
13. (a) Hydroid colony of *Obelia* is dimorphic, exhibiting two types of individuals or zooids which differ both morphologically as well as physiologically. These two zooids are-
- (i) Polyps – the nutritive zooid of the colony
- (ii) Gonangium – the reproductive zooid

14. (a) Alternation of generations may be defined as a phenomenon whereby, in the life history of an organism, a diploid asexual phase and a haploid sexual phase regularly alternates with each other. This type of true alternation of generations is also called metagenesis. In coelenterates, an asexual polypoid generation appears to alternate regularly with a sexual medusoid generation.
15. (a) Lateral line system of fishes and aquatic larval amphibians whose receptors are group of sensory cells derived from ectoderm.
16. (c) *F. hepatica* undergoes both aerobic and anaerobic respiration depending on the availability of oxygen. Oxygen content in bile being extremely low, respiration in *F. hepatica* is anaerobic or anoxybiotic. This is an exothermic reaction involving release of energy (heat). If free oxygen is available, aerobic respiration takes place.
17. (c) *Plasmodium vivax* is responsible for malaria. It spreads by bite of female *Anopheles*. Its spread does not have any relation with polluted water.
18. (a) Birds have many adaptations for flight. They have pneumatic bones and only one ovary which reduces the body weight.
19. (d) Shark is a cartilaginous fish and lack buoyancy regulating organ called Swim bladder. These fishes swim constantly or will sink to the bottom. They cannot stay at a desired level in water without swimming.
20. (b) Sponges belong to Porifera and they have characteristic canal system.
21. (c) Malaria can not be transmitted by the bite of male *Anopheles* mosquito. It does not carry active stage of *Plasmodium*.
22. (b) In cold blooded animals, there is no fat layer below skin and their temperature varies with the environment. These animals use their body fat during hibernation to carry out.
23. (b) Acraniata includes marine forms without head or cranium. They lack jaws, vertebral column, paired appendages.
24. (b) Spicules help in making skeleton of sponges. These are made up of silica, calcium or spongin substances. The structure of spicules also help in classification of sponges.
25. (c) Cephalization is the differentiation of head at anterior end. This does not play any role in appearance of animal but it may involve in accumulation of nervous tissue and sense organs in head.
26. (b) Insects blood is colourless. The blood also does not play any role in transport of oxygen. Insects have tracheal respiration.
27. (b) In lophodont condition, found in elephants, there is an intricate folding of enamel and dentine. Crescentic enamel cusps are connected by several transverse ridges called lophos. A single large lophodont molar, 30cm by 10cm, is present at one time in each half of each jaw. These are adapted to grind all sorts of plants, including grasses.
28. (b) One of the important human filaria is the African eye-worm *Loa loa*, transmitted by mangosfly chiefly found in Africa. They commonly invade subcutaneous tissue and during their migration may pass across the eye-ball, hence the name eyeworm.
- Loa microfilariae* is very injurious and fatal when they penetrate brain and spinal cord and perhaps carry neurotropic viruses. During their migration, they cause intense itching and swelling. They also cause swelling and pain in eyes, known as "calabar swellings".
29. (b) The body of annelids is divided into segments called metameres, externally ring like grooves (annuli) and internally by vertical partitions called septa. The external segmentation corresponds to internal segmentation. This phenomenon is called metamere or metameric segmentation. Phylum annelida represents the first group of metazoan animals developing a true coelom with metameric segmentation.
30. (b) In annelida, blood is red due to the presence of haemoglobin or erythrocrurin dissolved in plasma. RBCs are absent in them. Blood corpuscles are colourless. Instead of blood, leeches possess reddish haemocoelomic fluid that flows in haemocoelomic channels.
31. (c) In whale bone whales, teeth are absent. Instead, the upper jaw carries two transverse rows of numerous triangular fringed horny plates of baleen or whale bone. This serves as the effective sieve for straining plankton (mostly krill) which forms their chief food.
32. (a) In annelida four pairs of flask shaped sacs, each with a diverticulum for storage of sperms and large ampulla for their nourishment is present. Spermathecae occur in 6-9 segments. They receive sperm during copulation. As cross fertilization occurs in earthworm, the sperms of one worm are transferred to spermathecae of the other.
33. (c) Coprophagy is found in certain mammals (e.g. Rabbits). This is the process by which many rodents form a special kind of faeces from the contents of the caecum and these are reingested, so that the food passes through the digestive system second time. Rabbit is coprophagus in habit, eating its own faeces in order to get maximum amount of nutrient from its food. Faeces produced during night alone are eaten up which are soft and moist due to incompletely digested cellulose. Thus passing through the gut once more, the faeces are subjected once again to digestion and absorption.
34. (b) All the sternal parts of the thoracic ribs except the last five, attached the sternum below by hyaline cartilage. Therefore, they are called as true ribs. Actually last two pairs of ribs (11<sup>th</sup> and 12<sup>th</sup> pair) provided with the sternal parts and they are not connected with the sternum and hence, known as floating ribs. Floating ribs protect the kidney.

35. (b) Sweat glands produced from stratum germinativum, plays an important role in the regulation of body temperature. When the body temperature rises too much, the sweat glands are stimulated to take up water from blood vessels and to pour out their secretion on the general surface of the skin. Evaporation of sweat from the body surface uses up latent heat of vaporization from the skin, thus the extra heat of the body is used up and the body cools down reducing the temperature.
36. (c) Aquatic annelids excrete ammonia, and terrestrial species (earthworm) excrete urea. However, earthworms are less ureotelic than other terrestrial animals. Excretory fluid contains 40% urea, 20% ammonia and 40% amino acids and other nitrogenous compounds, but no uric acid or urate.
37. (a) Most arthropods certain molluscs and tunicates contain open circulatory system. In them, a fluid composed of blood mixed with tissue fluid bathes with internal tissues and organs directly. It oozes through spaces or cavities that surround the organs, this mixture of fluid is usually referred to as haemolymph
38. (a) Birds have a constant body temperature which commonly remains in between 104° to 112°F, even in subzero weather. Thus they are called homoiothermal. The feathers serve the most important function of retention of heat. Because the plumage forms an efficient, non-conduction covering with its innumerable dead air spaces, useful as insulation. In cold weather, the heat loss is reduced to minimum by fluffing out the feathers, which increases the depth of insulating material by adding to the air spaces within the feathery layers. In warm weather, the feathers are often held close to the body to allow some escape of body heat.
39. (e) Moulting or ecdysis occurs not only in invertebrates, but in birds also. In birds, shedding and replacement of feathers is moulting or ecdysis which takes place gradually, moulting usually takes an average time of six weeks. At the base of each feather follicle, a dermal papilla persists from which new feathers will form. Thus there is a continuous replacement of feather throughout life. The replacement of feathers is seasonal in some birds such as peacock, while in other birds such as pigeon it is gradual throughout the year
40. (b) Though pigeons have no mammary glands, (as they belong to class aves not to mammals), milk is secreted by them. The pigeons are oviparous, the eggs are laid in the nest and are incubated by the warmth of the parent's body and hatching occurs after a fortnight. The immature, helpless and featherless young ones are nourished by parents by a fatty curdy secretion, the pigeons milk which is secreted in their crop. The parental care and homing instinct are well developed in pigeons.
41. (b) The poison apparatus of snake consists of a pair of poison glands, their ducts and a pair of fangs. The poison glands are situated one on either side of the upper jaw. The poison glands are possibly the superior labial glands or parotid glands. The fangs are sharply pointed and are enlarged maxillary teeth.
42. (c) The hemipenes are the copulatory organs found in *Uromastix* and some other reptiles. These are two eversible hollow sacs lying under the skin behind the cloacal aperture at the base of the tail. Proximally, the hemipenes communicate with the urodaeum of the cloaca. During copulation, only one hemipenes, is inserted into the cloaca of the female. Erection of the hemipenes is due to the muscular action and filling with blood, then they are everted and become cylindrical and project beyond the cloaca.
43. (a) Parental care is clearly seen in amphibians. They protect their eggs by keeping them –  
(i) in enclosures in the water, (ii) In holes near water, (iii) In nests, on trees or on rocks, overhanging water, (iv) In transparent gelatinous bag in the water, (v) On trees or in moss, away from water. They also show direct nursing by the parent. The examples are –  
(i) Tadpoles transported from one place to another by males, (ii) Eggs protected by male who covers with his body, (iii) Eggs carried round the legs by the female, on the back of the female etc.
44. (a) The entire skin of frog serves as organs of touch as it is abundantly supplied with sensory nerve endings situated in the spaces between the cells. Thus the skin is called tangoreceptor. At places, groups of epidermal cells-tactile organs and patches are present. These are very much sensitive to touch and also to temperature. The tactile organs make the skin of frog sensitive to touch, heat, cold and the effects of the chemicals.
45. (a) From the diffused lymphatic system lymph is pumped back into veins by two pairs of lymph hearts. One of which is situated just behind the transverse processes of the third vertebra opening into the sub scapular veins, the second pair of lymph hearts is found on either side at the end of the urostyle. They open into the femoral vein
46. (b) In frog, most of the absorption takes place in intestine. The intestine of frog is so formed, that it gives the greater surface area. The intestine is the longest part of the alimentary canal where the absorption of the digested food materials take place.  
To increase the absorptive surface of the intestine, the internal lining of the intestine forms transverse folds in the duodenum and longitudinal folds in the region of the ileum and rectum.
47. (a) Amphibia is cold blooded or ectothermal animal as its body temperature does not remain constant but fluctuates with that of environment. Thus it is called poikilothermal animal. In winter the temperature of the body activities ceases down. In this condition it can not live more on the land, so it takes winter sleep or hibernation in underground. Similarly during the summer it once again goes underground to sleep as its all body activities are slowed down due to high temperature. This is known as summer sleep.
48. (c) In fishes, the heart is mainly two chambered one auricle and one ventricle. Heart of *Scoliodon* receives only deoxygenated or venous blood, hence named as venous heart. The auricle opens to the ventricle through atrioventricular aperture. Mainly the impure blood passes from the heart to the gills only once. Therefore, they have single circulation only.



49. (b) The ampullae of Lorenzini are found in clusters on the dorsal and ventral surfaces of the head embedded below the skin but opening externally on the surface of the skin. The ampullae of Lorenzini were formerly regarded as neuromast organs but Sand (1938) has proved that these are thermoreceptor organs. The change in the temperature of water is carried to the brain through the ampullary receptors.
50. (a) A faint line runs on either side of the body extending from the head to the posterior end of the tail, this is called lateral line (also called neuromast system). It marks the position of an underlying canal which runs along side of the body and contains special receptor organs. The lateral line canal extends anteriorly into the head, where it branches into several canals; at intervals these canals opens to the exterior through the pores. These canals contain neuromast organs like rheoreceptors or current receptors. The latter can perceive vibration of very low frequency and detect disturbances in water.
51. (b) Following are the characters of cyclostomes showing an advance over *Amphioxus*. A distinct head, however may be secondary, a so-called cranium, a more advanced brain, pro and mesonephric kidneys, secondary notochord, vertebrae introduced (lampreys) etc. Cyclostomes also have some particular specialization like tongue apparatus, sucking mouth with horny teeth, sac-like gill pouches, separate branchial sac with branchial basket etc.  
The degenerated characters of cyclostomes are –  
(i) tongue apparatus (ii) rudimentary paired eyes in hagfishes (iii) lack of exoskeleton (iv) reduced liver and lack of gall bladder and bile duct in adult lamprey.
52. (a) *Amphioxus* is devoid of heart, head, kidneys and paired limbs. Paired sense organs are absent here receptors are of primitive types. A complete notochord is persistent with no vertebral column. This shows that it has a simple organization compared to vertebrates because many important craniate structures are lacking in it. But it is definitely a simple chordate having a large number of primitive characters such as a notochord, dorsal hollow nerve cord, and gill clefts.
53. (a) The life cycle of fresh water mussel, including a parasitic glochidium larva on a fish host has many advantages. Besides affording protection and a means of nourishment, it ensures a far wide and more rapid dispersal of the species. A fish may carry these tiny parasites to great distances before they drop off. Considering the sluggish habits and poor locomotory ability of the mussels, this is probably the only way to ensure their proper distribution.
54. (a) In *Amphioxus* some exchange of  $O_2$  and  $CO_2$  occurs between the water current and blood through the gill-clefts, but this appears doubtful since the blood contains no respiratory pigment. The pharyngeal wall of *Branchiostoma* is richly vascular and the water current entering the pharyngeal cavity brings  $O_2$ . The blood flows so close to the surface that some exchange between  $CO_2$  of blood and  $O_2$  of water can easily occur. It appears more probable that an exchange of gases occurs over the whole surface of the body and particularly in the walls of atrium.
55. (b) Torsion or twisting is a process during larval development of gastropods, which rotates the visceropallium anticlockwise brought  $180^\circ$  from its initial position, so that mantle cavity, with its pallial complex, is through in front of the body in adult. Changes occurring in torsion are to certain extent reversible. This reversion is known as detorsion and it is a very characteristic of the whole group of the euthyneura. Formerly, this condition was looked upon as an arrested stage in the torsion, but there is the same reduction of the paired parts of the pallial complex as in the specialized streptoneura. Total detorsion, as shown by the typical opisthobranchia is accompanied by the reduction or disappearance of the shell.
56. (c) Each ambulacral groove of echinoderms contains two double rows of short, tubular retractile projections, called as podia or tube feet, that end in suckers. Tube feet are characteristic organs of echinoderms serving variously for locomotion, capturing of food, respiration etc.
57. (c) In the mid ventral wall of pharynx is a shallow groove called endostyle. The endostyle is lined with gland cells which secrete mucus. The larval endostyle is lost during metamorphosis of lamprey, it contributes to the formation of a thyroid gland in the adult. Like thyroid it concentrates radioactive iodine in itself. Similar endostyle is found in urochordate and the ammocoete larva of lampreys.
58. (a) Digestive mechanism of *Herdmania* is similar to that of higher group of animals due to possessing several enzymes used in digestion. In *Herdmania*, the liver secretes a yellowish-brown digestive fluid into the stomach, it has many enzymes, an amylase which splits carbohydrates into maltose, a protease which breaks down proteins and a weak lipase which probably acts on fats. And also secretion of pyloric gland probably has an accessory digestive function similar to that of pancreas.
59. (d) Pygochord is longitudinal rod like structure extending from the ventral side of the intestine to the body wall, in the post hepatic region of the trunk. Its cells are vacuolated. It supports the post hepatic region of the body but probably also performs some other functions not yet understood.
60. (b) Water vascular system or ambulacral system is a unique system of echinoderms which helps mainly in locomotion. It is infact a modified part of coelom consisting of a system of canals containing sea water and amoeboid corpuscles. It helps in locomotion by providing a hydraulic pressure mechanism of tube feet may serve for respiratory exchange of gases. Tube feet also help in anchoring the body to substratum and in capturing and handling the food.
61. (c) *Balanoglossus* belong to class enteropneusta. In certain cases, the proboscis pore does not communicate with the proboscis coelom, but terminate blindly, and may send off a narrow tubular diverticulum which opens into the neurocoel. The proboscis sits in the collar somewhat like an acorn in its cup, a character that has given the name "acorn worm" to the group.



## Animal Kingdom

## Self-Evaluation Test

- Select incorrect pair [MP PMT 2009]  
(a) Porifera-choanocytes (b) Coelenterata-nematocysts  
(c) Annelida – segmentation (d) Monera – eukaryote
- Which of the following is a chordate feature, not shared by the non-chordates [AIIMS 2001; CBSE PMT 2002; CPMT 2005]  
(a) Metamerism (b) Axiate organization  
(c) Bilateral symmetry (d) Pharyngeal gill slits
- Which one of the following invertebrates is a deuterostome and enterocoelous coelomate [MP PMT 2000]  
(a) Pila (b) Ascaris  
(c) Aphrodite (d) Asterias
- Helically coiled shaped “X” organ is found in [Odisha JEE 2008]  
(a) Crustacea (b) Porifera  
(c) Insecta (d) Amphibia
- Scollodon* is called dogfish due to one of its following characteristics [MP PMT 2000]  
(a) Mouth (b) Gait  
(c) Carnivorous (d) Power of smell
- The stages between larval moults in an insects are called [Odisha JEE 2008; J & K CET 2012]  
(a) Instar (b) Morula  
(c) Pupa (d) Larva
- Scales in chondrichthyes are [AIIMS 2000; MP PMT 2011]  
(a) Placoid (b) Ganoid  
(c) Cycloid (d) Sesamoid
- Which one of the animal of amphibia has no tongue  
(a) *Amphiuma* (b) *Ichthyophis*  
(c) *Necturus* (d) *Salamander*
- Comb plates are found in [J & K CET 2008]  
(a) *Adamsia* (b) *Aurelia*  
(c) *Nereis* (d) *Pleurobrachia*
- Sharks and dogfishes differ from skates and rays by [NEET (Karnataka) 2013]  
(a) Gill slits are ventrally placed  
(b) Head and trunk are widened considerably  
(c) Distinct demarcation between body and tail  
(d) Their pectorals fins distinctly marked off from cylindrical bodies
- Which of the following is not found in birds [CBSE PMT 1999]  
(a) Hind limb (b) Fore limb  
(c) Pelvic girdle (d) Pectoral girdle
- Biradial symmetry is found in [Odisha JEE 2010]  
(a) *Beroe* (b) *Hydra*  
(c) Sponges (d) *Labeo*
- Paired appendages are not found in [AFMC 2008]  
(a) Hemichordates (b) Urochordates  
(c) Cephalochordates (d) All of these
- Which of the following group is Deuterostome [Kerala PMT 2000; RPMT 2001]  
(a) Annelida, Arthropoda, Mollusca  
(b) Echinodermata, Hemichordata, Chordata  
(c) Annelida, Mollusca, Chordata  
(d) Arthropoda, Mollusca, Echinodermata
- Discoblastula* found in [MP PMT 2011]  
(a) Echinoderms and amphioxus  
(b) Reptiles, birds and fishes  
(c) Annelids, molluscs and nemertens  
(d) Insects
- Which is not a bird [MP PMT 2011]  
(a) *Columba* (b) *Testudo*  
(c) *Pavo* (d) *Struthio*
- The paralyzing toxin in nematocyst [RPMT 1999; AIIMS 2000; CPMT 2001; MH CET 2002, Pb. PMT 2004]  
(a) Glutathione (b) Heparin  
(c) Histamine (d) Hypnotoxin
- Dropping of gravid proglottids by cestodes is called [MP PMT 2000]  
(a) Apolysis (b) Autotomy  
(c) Paedogenesis (d) Autophagy
- Calotes versicolor* belongs to class [Odisha JEE 2009]  
(a) Osteichthyes (b) Amphibia  
(c) Reptiles (d) Aves
- Chloragogen cells of earthworm are similar to the organ of vertebrate's [CPMT 1999, 2004; MH CET 2002]  
(a) Liver (b) Lung  
(c) Kidney (d) Spleen

21. Interstitial fluid resembles [Odisha JEE 2009]  
(a) Sea water (b) Fresh water  
(c) Ground water (d) None of these
22. The modification of second pair of wings into halteres or balancers is the characteristic of [MP PMT 2001]  
(a) Lepidoptera (b) Orthoptera  
(c) Diptera (d) Hemiptera
23. Mesoglea is seen in between [NCERT; WB JEE 2008]  
(a) Ectoderm and endoderm  
(b) Ectoderm and mesoderm  
(c) Mesoderm and endoderm  
(d) Just below mesoderm
24. Flagellated collar cells (choanocytes) is the characteristics of [MP PMT 2011]  
(a) Cnidaria (b) Arthropoda  
(c) Porifera (d) None of the above
25. In which one of the following groups an animals are hermaphrodite [MP PMT 2001]  
(a) Hydra, Ascaris, Pheretima  
(b) Hydra, Homo sapiens, Leech  
(c) Tapeworm, Toad, Starfish  
(d) Hydra, Leech, Tapeworm
26. Which of the following is a correct sequence of decreasing order of number of species [BHU 2008]  
(a) Aves, pisces, reptiles, amphibians, mammals  
(b) Pisces, aves, reptiles, mammals, amphibians  
(c) Pisces, mammals, reptiles, amphibians, aves  
(d) Amphibians, aves, pisces, mammals, reptiles
27. In *Hydra*, digestion is [BHU 1999; CPMT 1999]  
(a) Extracellular  
(b) Intracellular  
(c) First extracellular and then intracellular  
(d) First intracellular and then extracellular
28. Infective stage of *Ascaris* is [CBSE PMT 1997; KCET 1998; RPMT 1999, 2002; BHU 2002; WB JEE 2008]  
(a) Adult worm (b) Second juvenile  
(c) Fourth juvenile (d) Egg
29. How are annelida advanced over nematoda [Pb. PMT 1999]  
(a) Closed circulation (b) True coelom  
(c) Metameric segmentation (d) All of these
30. Two pairs of antennae are found in class [EAMCET 1998]  
(a) Myriapoda (b) Crustacea  
(c) Insecta (d) Arachnida
31. Which is the correct order of evolution [CPMT 1998]  
(a) *Leucosolenia* – *Hydra* – *Amoeba* – *Ascaris*  
(b) *Ascaris* – *Amoeba* – *Leucosolenia* – *Hydra*  
(c) *Amoeba* – *Leucosolenia* – *Hydra* – *Ascaris*  
(d) None of these
32. Which one of the following is correctly paired [Kerala PMT 2007]  
(a) *Trygon* - Monitor  
(b) *Ichthyophis* - Crow  
(c) *Varanus* - Stingray  
(d) *Corvus* - Limbless amphibian  
(e) *Pristis* - Sawfish
33. Which is vivipary [BVP 2003; Bihar CECE 2006]  
(a) Whale, rabbit (b) Frog, kangaroo  
(c) Snake, lizard (d) Cockroach, aves
34. Antennary glands of crustaceans are meant for [DPMT 2006]  
(a) Excretion (b) Respiration  
(c) Digestion (d) Circulation
35. Pancreas is absent in which group of vertebrates [DPMT 2006]  
(a) Reptiles (b) Cyclostomates  
(c) Birds (d) Mammals
36. Praying mantis is a good example of [CBSE PMT 2006]  
(a) Social insects (b) Camouflage  
(c) Mullerian mimicry (d) Warning colouration
37. Biradial symmetry and lack of cnidoblasts are the characteristics of [CBSE PMT 2006]  
(a) *Aurelia* and *Parametrium* (b) *Hydra* and starfish  
(c) Starfish and sea anemone (d) *Ctenophora* and *Beroe*
38. What is common between parrot, platypus and kangaroo [CBSE PMT 2007]  
(a) Homoeothermy (b) Toothless jaws  
(c) Functional post-anal tail (d) Ovoparity
39. Which one of the following is a matching pair of a body feature and the animal possessing it [CBSE PMT 2007]  
(a) Post-anal tail – Octopus  
(b) Ventral Central nervous system – Leech  
(c) Pharyngeal gill slits absent in embryo – Chameleon  
(d) Ventral heart – Scorpion
40. Axis vertebra is identified by [MP PMT 2009]  
(a) Sigmoid notch (b) Deltoid ridge  
(c) Odontoid process (d) Centrum

41. The most primitive vertebrates are [MP PMT 2009]

- (a) Ostracoderms (b) Cephalochordates  
(c) Placoderms (d) Cyclostomes

42. In anura group of frog, caudal vertebra fused to form [Odisha JEE 2008]

- (a) Coccyx (b) Urostyle  
(c) Pygostyle (d) Prehensile tail

43. The extinct reptiles without temporal fossae belong to [EAMCET 2009]

- (a) Chelonia (b) Synaptosauria  
(c) Ichthyopterygia (d) Cotylosauria

## AS Answers and Solutions

1	d	2	d	3	d	4	a	5	d
6	a	7	a	8	b	9	d	10	d
11	b	12	a	13	d	14	b	15	b
16	b	17	d	18	a	19	c	20	a
21	a	22	c	23	a	24	c	25	d
26	b	27	c	28	b	29	d	30	b
31	c	32	e	33	a	34	a	35	b
36	b	37	d	38	a	39	b	40	c
41	a	42	b	43	d				

2. (d) Chordates show the presence of nerve cord, Notochord and pharyngeal gill slits.
3. (d) Echinodermata and all chordates are deuterostome and enterocoelous.
5. (d) In scoliodon, olfactory organs are characteristically large in elasmobranchs correlated with a highly developed sense of smell for perception of chemical substances dissolved in water.
7. (a) Placoid scale has a disc like basal plate. It resembles a tooth. These scales are found in cartilaginous fishes (chondrichthyes).
8. (b) Ichthyophis is a limbless amphibian showing parental care. It has no tongue.
10. (d) Sharks and dogfishes have cylindrical body while skates and rays have flattened body with winglike pectoral fins which are not distinct from body.

11. (b) In birds, forelimbs are modified as wings for flying. Therefore, the forelimb is not found in birds.

14. (b) Deuterostomes includes Echinodermata, Hemichordata and chordata. The mouth is derived away from the blastopore.

17. (d) Hypnotoxin is secreted by nematocyst cell of tentacles of hydra to paralyse the active prey for easy engulfing.

18. (a) Loss of gravid proglottids from posterior end of body is called apolysis.

20. (a) Because they are supposed to be associated with the function of excretion just like liver.

22. (c) In diptera, hindwings are greatly reduced to drumstick shaped structures, called halteres. These carry sense organs and serve as balancing organ during flight.

25. (d) An individual with both male and female reproductive organs called hermaphrodite.

28. (b) The second stage of juvenile is infective stage of *Ascaris* which is also called embryonated egg.

29. (d) Annelids are first animals in which closed circular system, metamerism segmentation and true coelom is evolved. On the basis of these comments annelids are advanced over nematoda.

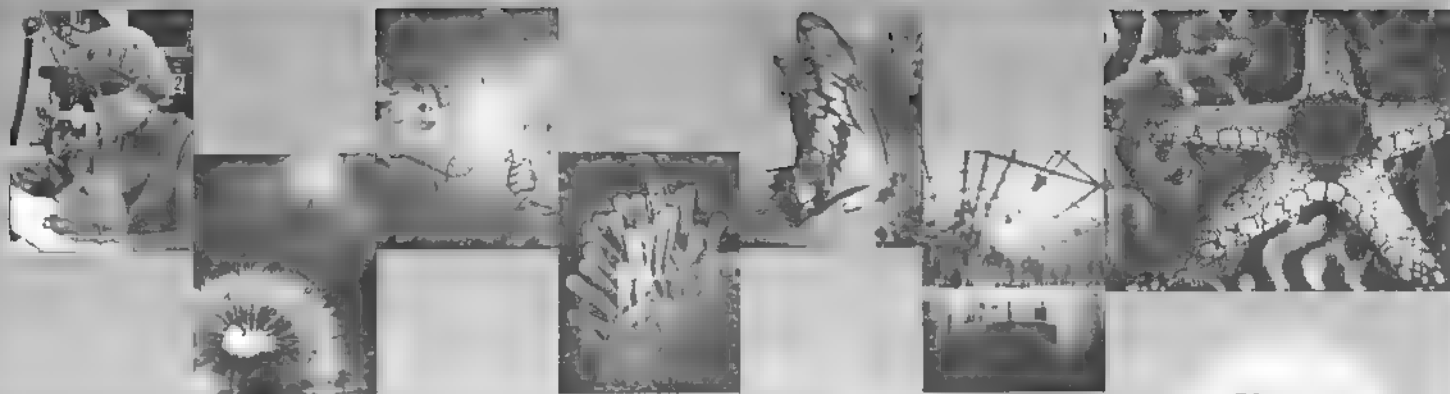
30. (b) Presence of two pair antennae is character of class crustacea. Antennae are sensory and help in searching food and shelter.

34. (a) The excretory system of crustacea (*Palaemon*) consists of a pair of antennary or green glands, a pair of lateral ducts and an unpaired renal or nephroperitoneal sac. Coxa of each antenna encloses an antennary gland.

35. (b) Pancreas is absent in cyclostomates, a class of Agnatha. The pancreas is derived from the endoderm of embryo. It lies inferior to the stomach in a bend of the duodenum. It is both an exocrine and endocrine gland.

38. (a) All these three animals are Homeiothermic; although platypus is incomplete homeiothermic.

39. (b) In invertebrates nerve cord is found in ventral position that is a part of CNS.



## Chapter 2.1

# Morphology of Flowering Plants

Morphology (Gr. Morphos = Form; logos = Study) is the branch of science which deals with the study of form and structure. In botany, it generally means the study of external features, forms and relative positions of different organs on plants.

**Parts of a flowering plant :** Flowering plants consist of root, stem, leaves, flower, fruits and seeds

### The root

The root is usually an underground part of the plant which helps in anchorage of plant in soil and absorption of water and minerals from the soil. The root with its branches is known as the root system.

#### Characteristics of the root

- (1) The root is the descending portion of the plant axis and is positively geotropic and negatively phototropic.
- (2) It is non-green or brown in colour.
- (3) The root does not bear nodes, internodes, leaves and true buds.
- (4) Usually the root tip is protected by a root cap.
- (5) The root bears unicellular root hairs.
- (6) Lateral roots arise from the root which are endogenous in origin (arise from pericycle).

#### Parts of the root

(1) **Region of root cap :** The tip of the root is called calyptra or root cap. It is for protection of root tip against any injury. It is formed from meristem called calyptragen. *Pandanus* is the only plant with multiple root caps. In the aquatic plants like *Pistia*, *Lemna* and *Eichhornia* instead of root caps, they have root pockets for buoyancy. The root caps are absent in parasites and mycorrhizal roots.

(2) **Region of cell formation or meristematic zone :** This region of cell division lies protected below the root cap. It comprises of closely arranged, small, thin walled and isodiametric cells which have dense protoplasm. Vacuoles of the cells are either reduced in size or absent.

(3) **Region of cell elongation :** It lies behind the growing point. Cells of this region lose power of division. The cells elongate due to vacuolation i.e., formation of vacuoles.

This region chiefly concerns with absorption of minerals along with some amount of water.

(4) **Region of cell differentiation or maturation (Root hair zone) :** In this region elongated cells are differentiated into permanent tissues depending upon the functions they have to perform. It lies adjacent to the meristematic region some cell of the outermost layer of cells in this region develop root hairs. Most of the water absorption occurs through this region.

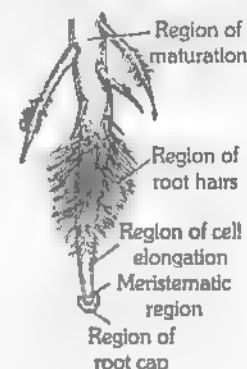


Fig : 2.1-1 Regions of the root

#### Types of root

**Tap root :** Tap root is the primary root which develops from the elongation of the radicle of embryo and persists throughout the life of plant. It forms lateral branches or secondary roots which are further branched to form tertiary roots. Thus tap root along with its branches i.e., secondary and tertiary roots form tap root system.

**Adventitious root :** The root system that develops from any part of the plant body other than the radicle is called the adventitious root system. It is mostly seen in monocotyledonous plants. In grasses, fibrous root system is present.

## Modification of roots

Sometimes the root performs functions other than fixation, absorption and conduction so get modified structurally. Both tap roots and adventitious roots may undergo such modifications. There are many types of root modifications.

### Modification of tap roots

(1) **Storage roots** : In some plants, the primary tap roots are modified for storing reserve food materials. The secondary roots remain thin and they are absorptive in function. The storage roots are usually swollen and assume various forms :

(i) **Conical** : The swollen root is broad at the base and tapers gradually towards the apex giving a shape of cone, e.g., Carrot.

(ii) **Fusiform** : The root is swollen in the middle and narrow towards both its base e.g., Radish (*Raphanus sativus*).

(iii) **Napiform** : The root is nearly globular or spherical in shape. The basal portion of root is much swollen which suddenly tapers towards the apex giving a top-shaped appearance, e.g., Turnip (*Brassica napus*, vern. Shalgam) and Beet (*Beta vulgaris*, vern. Chukandar).

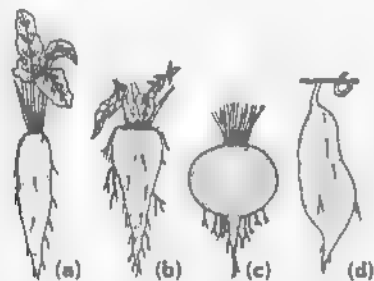


Fig : 2.1-2 Tap root modifications (a) Fusiform (b) Conical (c) Napiform (d) Tuberous

(iv) **Tuberous** : The storage root having no definite shape is called tuberous, e.g., *Mirabilis jalapa* (4 O'clock plant).

### (2) Branched roots

(i) **Nodular roots (Tuberculated roots)** : The primary tap roots and its branches of leguminous plants, i.e., plants belonging to sub-family papilionatae of the family leguminosae (e.g., Pea, Gram, Ground nut, Beans etc.), bear nodule like swellings, called root nodules.

They are red in colour due to the presence of leg-haemoglobin. The nodules are inhabited by nitrogen fixing bacteria called *Rhizobium leguminosarum*. It converts atmospheric nitrogen into nitrates and supply them to the plant. In turn *Rhizobium* gets nutrients and shelter from the plant.

(ii) **Pneumatophores or Respiratory roots** : The roots of some plants growing in saline marshes (mangrove plants) suffer from the lack of oxygen. This is due to the water logged condition of the soil. To cope with this situation some root branches grow vertically upwards.

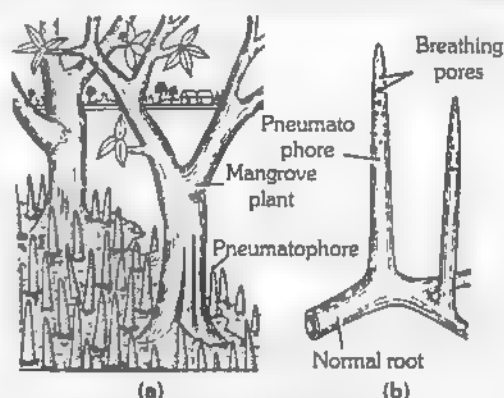


Fig : 2.1-3 Pneumatophores :  
(a) Plants showing pneumatophores  
(b) Part of pneumatophores showing breathing pores

They become aerial and negatively geotropic. These roots bear many minute pores called pneumathodes (lenticels) towards their upper ends. Gaseous exchange takes place through pneumathodes. Such aerial, porous, roots which help in gaseous exchange are called breathing roots. e.g., *Sonneratia*, *Heritiera*, *Rhizophora*, *Avicennia* and *Ceriops* etc. and are found in sundarbans of West Bengal.

### For physiological or Vital functions

(1) **Storage roots** : The roots where adventitious roots become swollen to store food. They are of following types :

**Tuberous roots** : These adventitious roots are swollen without any definite shape e.g., *Ipomoea batata* or (Sweet potato).

**Fasciculated roots** : These are tuberous roots arising in cluster from the base of the stem. e.g., *Dahlia*, *Ruellia* (Menow weed), *Asparagus* etc.

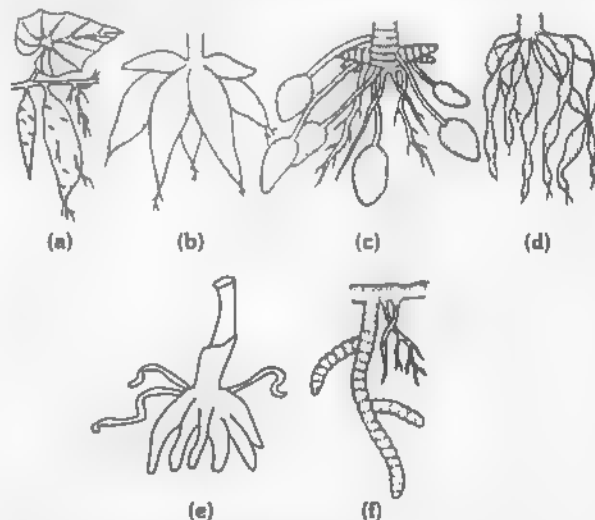


Fig : 2.1-4 Modification of adventitious root : (a) Tuberous root of sweet potato (b) Fasciculated roots of dahlia, (c) Nodulose roots of mango ginger, (d) Moniliform root of *Momordica*, (e) Palmate roots of *Orchis*, (f) Annulated roots of *Ipecac*

**Nodulose roots** : These roots become swollen at their tips due to accumulation of food e.g., *Maranta* sp. (Arrowroot), *Curcuma amanda* (Mango – ginger).

**Moniliform or Beaded roots :** These adventitious roots are swollen at frequent intervals. This gives the root a beaded appearance. e.g., *Portulaca* (Rose moss), *Momordica* (Bitter gourd), *Cyperus* (Guinea rush).7

**Palmate tuberous roots :** In *Orchis* there is a pair of succulent tuberous root, one of which perishes every year while another new one is formed by its side. Such orchid roots may sometimes be of palmate shape, therefore, called palmate roots.

**Annulated roots :** The roots of a medicinal plant, *Cephaelis ipecacuanha* (Ipecac) yields emetine that looks like discs placed one above another, therefore, called annulated.

(2) **Epiphytic roots :** These roots are also called 'hygroscopic roots'. These roots develop in some orchids which grow as epiphytes upon the trunks or branches of trees. They hang freely in the air and absorb moisture with the help of special sponge like tissue called velamen. Velamen is modification of epidermis. e.g., *Vanda*, *Dendrobium* etc.

(3) **Parasitic or Haustorial or Sucking roots :** The roots of parasitic plants, which penetrate into the host tissues to absorb nourishment, are called haustorial roots. e.g., *Cuscuta* (Dodder, Vern, Amarbel).

(4) **Saprophytic roots (Mycorrhizal roots) :** The roots are associated with fungal hyphae either superficially (ectomycorrhizae) or internally (endomycorrhizae) for absorption of water and minerals. e.g., *Monotropa* and *Sarcodes*.

(5) **Photosynthetic or Assimilatory roots :** These are green, aerial, adventitious roots which prepare food materials by photosynthesis are called photosynthetic roots or assimilatory roots e.g., *Taeniophyllum*, *Trapa* and *Tinospora*. In some epiphytes like *Taeniophyllum*, the stem and leaves are absent. The entire plant is represented by thin green, ribbon like roots which contain velamen. These roots absorb moisture from the atmosphere and manufacture food materials by photosynthesis.

(6) **Reproductive roots :** Some fleshy adventitious root develop buds which can grow into new plants. These are called reproductive root. These roots serve as means of vegetative propagation. e.g., Sweet potato, *Dahlia* etc.

#### For mechanical function

(1) **Stilt roots (Brace roots) :** The aerial, adventitious obliquely growing roots that develop from the lower nodes of the stem to give additional support are called stilt roots. These roots bear several large overlapping root caps called multiple root caps. e.g., *Sugarcane*, *Pandanus*, *Rhizophora*, *Sorghum* and *Maize*. *Pandanus* (screw pine) is a common sea shore plant.

(2) **Prop roots or Pillar or Columnar roots :** These adventitious aerial roots arise from horizontal aerial branches of the trees like *Ficus benghalensis* (Banyan). They grow vertically downward, penetrate the soil, become thick and assume the shapes of pillars. They provide support to the spreading branches of tree. Prop roots possess lenticels for aeration.

In India, the biggest banyan tree having large number of prop roots are found at Indian Botanical Gardens, Kolkata and Kadiri (Andhra Pradesh).

(3) **Buttress roots :** The horizontal plank like aerial, adventitious roots that develop at the base of the stem to give additional support are called buttress roots or ballast roots, e.g., *Terminalia* and *Salmalia*.

(4) **Climbing roots :** The aerial adventitious roots that arise from the nodes or internodes of weak stemmed plants to climb up their support are called climbing roots, e.g., *Pothos*, *Piper betel*, *Vanilla* and *Hedera*. In *Pothos* and *Hedera*, climbing roots develop all over the stem. In *Vanilla*, single tendril like root arise at each node. Hence they are called tendrillar roots. In *Piper betel*, many short branched, adventitious roots arise at each node. These roots are called clinging roots.

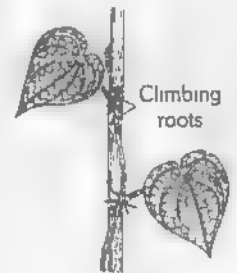


Fig : 2.1-5 Climbing root of *Piper betel*

(5) **Floating roots :** These roots develop from the nodes of floating aquatic plants like *Jussiaea* (= *Ludwigia*). They store air, become inflated and spongy, project above the level of water, make the plant light and function as floats.

(6) **Contractile or Pull roots :** Some roots of plants with underground stems contract or swell so that the aerial shoots are kept in a proper depth in the soil. These roots are called contractile or pull roots, e.g., *Canna*, *Crocus*, *Allium*, *Lilium*, *Freesia*, etc.

(7) **Root thorns :** In aroids like *Pothos* and many palms (*Acanthorhiza* and *Iriarteia*) the adventitious roots become hard and pointed hence called root thorns.

#### The stem

The stem develops from the plumule of the germinating seed. Normally it is the aerial part of the plant body.

#### Characteristics of stem

(1) Stem is an ascending axis of the plant and develops from the plumule and epicotyl of the embryo.

(2) It is generally erect and grows away from the soil towards light. Therefore, it is negatively geotropic and positively phototropic.

(3) The growing apex of stem bears a terminal bud for growth in length.

(4) In flowering plants, stem is differentiated into nodes and internodes. A node occurs where leaves are attached to the stem. Internode is the portion of stem between the two nodes.

(5) The lateral organs of stem (i.e., leaves and branches) are exogenous in origin (from cortical region).

(6) The young stem is green and photosynthetic.

(7) Hair, if present, are generally multicellular.

(8) In mature plants, stem and its branches bear flowers and fruits.

### Diverse forms of stem

(1) **Reduced stems** : In some plants, the stem is in the form of a reduced small disc which is not differentiated into nodes and internodes. e.g., (a) A reduced green-coloured disc-like stem lies just above the base of fleshy roots of Radish, Carrot and Turnip ; (b) Green-coloured small discoid stem occurs in free-floating *Lemna*, *Spirodela* and *Wolffia*; (c) Highly reduced non-green discoid stem occurs at the base of Onion and Garlic bulbs, etc

(2) **Erect stems** : Majority of angiosperms possess upright, growing-ascending, vertically-erect stems. They are fixed in the soil with the help of roots.

(3) **Weak stems** : They are thin, soft and delicate which are unable to remain upright without any external support. They are of two types : upright weak stems and prostrate weak stems.

#### (i) Upright weak stem

**Twiners** : The stems are long, slender, flexible and very sensitive. They twin or coil around an upright support on coming in its contact due to a special type of growth movement called nutation. They may coil the support to the right (anticlockwise from the top or sinistrorse) e.g., *Convolvulus* sp., *Ipomoea quamoclit* *Clitoria ternatea*, etc. or to the left (clockwise or dextrorse), e.g., *Lablab*

**Climbers** : The stem is weak and unable to coil around a support. They usually climb up the support with the help of some clasping or clinging structure. They are of four types .

(a) **Tendrill climbers** : Tendrils are thread like green structure which help in climbing the plants. They may be modified stem (e.g., *Vitis*), stem branches (e.g., *Passiflora*) and inflorescence (e.g., *Antigonon*).

(b) **Root climbers** : Adventitious roots arise from the nodes and penetrate into the upright support so that the climber climbs up, e.g., Betel vine (*Piper betel*), *Tecoma*, *Ivy*, etc.

(c) **Scramblers or Hook climbers** : These weak stemmed plants slowly grow over other bushes and rest there. They attain this position with the help of curved prickles (e.g., *Rose*), curved hooks on flowering peduncle (e.g., *Artabotrys*), prickles on stem (e.g., *Lantana*), spines (e.g., *Climbing Asparagus*) or spinous stipules (e.g., *Zizyphus*).

(d) **Lianas** : These are woody perennial climbers found in deep forests. At first, they are just like ordinary twiners but once they reach to the top and get sunlight, become woody. e.g., *Tinospora*, *Ficus*, *Bauhinia*, *Bignonia*, etc.

#### (ii) Prostrate weak stem

**Trailers** : The stem creep on the ground but roots do not arise at the nodes. They are of three types :

(a) **Procumbent** : The stem creeps on the ground totally e.g., *Tribulus*, *Basella*, *Evolvulus*.

(b) **Decumbent** : Branches, after growing horizontally for some length, grow vertically upwards, e.g., *Portulaca*, *Tridax*, *Lindenbergia*, etc.

(c) **Diffuse** : Branches grow profusely in all directions, e.g., *Boerhaavia*.

**Creepers** : These weak-stemmed plants grow prostrate and develop adventitious roots from their nodes. Creepers are of three kinds

(a) **Runners** : This prostrate aerial stem has a long internode and creeps horizontally. Axillary buds arise from nodes to form aerial shoots and roots. e.g., *Cynodon* (doob grass) and *Oxalis*.

(b) **Stolons** : They are special kinds of runners which initially grow upwards like ordinary branches and then arch down to develop new daughter plants on coming in contact with the soil. e.g., Strawberry (*Fragaria vesica*), *Colocasia*, Peppermint (*Mentha piperita*), *Jasminum* (*Jasmine*).

(c) **Offsets** : They are weak, elongated, horizontal branch of one internode that arises in the axil of a leaf. At the tip, it produces cluster of leaves above and tuft of roots below. The offset may break off from the parent plant and act as individual plants. They are found usually in aquatic plants and rarely in terrestrial plants. They are helpful for vegetative propagation. e.g., *Elchhornia* (water hyacinth), *Agave*, *Pistia*.

### Modification of stem

#### Underground stem

The underground stems lack green colour because of their geophillous nature. They can be identified as stems because of the presence of nodes, internodes, scale leaves, buds and branches. Based on the type of growth (transverse/vertical/oblique) and the part that stores food (main stem/ branch/ leaf base), the underground stems are classified into several types :

(1) **Sucker** : This is a sub aerial branch that arises from the main stem. Initially it grows horizontally below the soil surface and later grows obliquely upward. They are shorter and stouter than the runners. e.g., *Mentha arvensis* (mint vern. Podina) and *Chrysanthemum*.



Fig : 2.1-6 Sucker

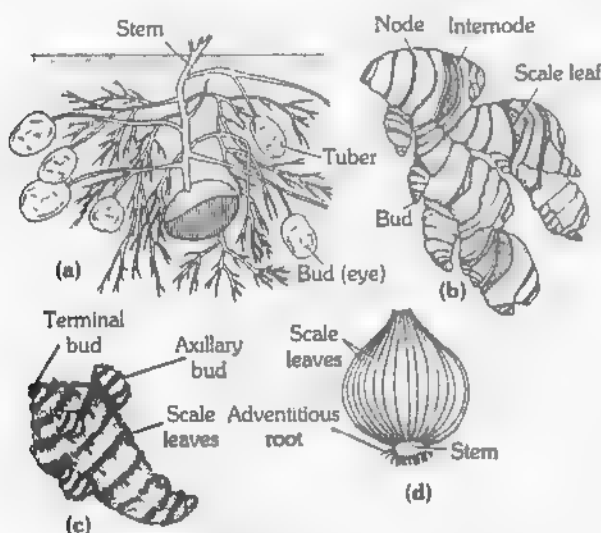
(2) **Stem tuber** : Stem tuber is the tuberous tip of an underground branch. It occurs beneath the soil at any depth. The axillary branches (stolons) that are produced near the soil surface grow into the soil and their tip become swollen due to accumulation of starch and proteins e.g., *Solanum tuberosum* (potato). In potato, the stem nature is evident by the presence of 'eyes' on its brownish corky surface. Each eye is a pit like structure and represents the node. Axillary bud is situated in the pit of the eye. The stem tubers are differentiated from the tuberous roots by the presence of vegetatively propagating eyes.

(3) **Rhizome** : The rhizome is a thickened, underground dorsiventral stem that grows horizontally at particular depth within the soil. The rhizome is brown in colour. It can be distinguished from the modified root by the presence of nodes, internodes, terminal bud, axillary bud and scale leaves. The terminal bud develops aerial shoot that bears inflorescence. Adventitious roots develop on the ventral surface of the rhizome. The rhizomes are perennial and vegetatively propagating structures. It is of following types :

(i) **Rootstock** : They are upright or oblique or vertical with their tips reaching the soil surface. e.g., *Alocasia indica* and Banana.

(ii) **Straggling** : They are horizontal in position and generally branched (Sympodial or Monopodial), e.g., *Nelumbo nucifera* (Lotus), *Zingiber officinale* (Ginger), *Curcuma domestica* (Turmeric), *Saccharum* etc.

(4) **Corm** : The corm is an underground modification of main stem with more diameter than length. It grows vertically at particularly depth in the soil. The corm stores food materials and becomes tuberous. It is non green in colour and conical, cylindrical or flattened in shape. The corm bears scale leaves at each node. In the axils of these scale leaves axillary buds arise which grow into daughter corms. The terminal bud of the corm is large.



**Fig : 2.1-7 Underground modification of stem**  
(a) Tuber of potato (b) Rhizome of ginger  
(c) Corm of colocasia (d) Bulb of onion

It grows into aerial shoot and bears leaves and flowers. Adventitious roots normally develop from the base or all over the body of the corm. With the help of some special adventitious roots called the contractile roots or pull roots, the corm remains constantly at a particular depth. The corm propagates vegetatively by daughter corms. e.g., *Amorphophallus*, *Gladiolus*, *Colocasia* and *Crocus* (Saffron).

(5) **Bulb** : A bulb is a specialized underground stem which bears roots on its lower side and rosette of fleshy leaf bases or fleshy scales on the upper side. In a bulb, the stem is reduced and

becomes discoid. On the lower side of the disc adventitious roots develop in clusters. The upper side of the disc shows compactly arranged scale leaves so as to form an underground bulb. The leaf bases or scales become fleshy due to accumulation of food (carbohydrates) and water. The terminal bud grows into inflorescence or aerial shoot (scape), while some of the axillary buds develop into daughter bulbs. Bulbs are of two types, tunicated bulb and scaly bulb.

(i) **Tunicated bulb** : In tunicated bulb, the fleshy leaf bases are arranged in a concentric manner. The entire bulb is covered by peripheral dry membranous leaf bases called tunics, hence called the tunicated bulb. e.g., *Allium cepa* (Onion), *Narcissus* and *Tulip*. Compound tunicated bulbs as in *Allium sativum* (garlic).

(ii) **Scaly or Imbricated bulb** : In scaly bulb, the fleshy scale leaves are arranged loosely overlapping one another. Such bulbs are not covered by any tunics, hence called naked bulbs or scaly bulbs. e.g., *Lilium bulbifera* (Lily).

#### Aerial stem

(1) **Tendrils** : The tendrils are thin, wiry, leafless and spirally coiled branches. The terminal part of a tendril is sensitive. It holds the support by coiling round it. The tendrils help the weak stems to climb the support. In some weak stemmed plants, the axillary bud or terminal bud may modify to form tendrils which are specially called stem tendrils. Stem tendrils are of following four types :

(i) **Axillary** : e.g., *Passiflora*.

(ii) **Extra-axillary** : e.g., *Luffa* (vern. Ghiatori), *Cucurbita* (vern. Kaddoo), *Lagenaria* (vern. Lauki).

(iii) **Apical bud tendrils** : e.g., Grape Vine (*Vitis vinifera*).

(iv) **Floral bud or Inflorescence tendrils** : e.g., *Antigonon*.

(2) **Stem thorns** : The axillary buds of some plants become arrested and get modified into stiff, sharp and pointed structures, called thorns. They are deep seated structures having vascular connections with stem. Besides reducing transpiration, they protect the plant from browsing animals. e.g., *Citrus*, *Duranta*, *Bougainvillea*, *Pomegranate*, *Flacourtia*, *Aegle marmelos* etc. In *Alhagi* the thorns bear flowers.

(3) **Phylloclades** : The phylloclade is special modified photosynthetic stem present mostly in xerophytes. It is green, flattened or cylindrical structure which has distinct nodes and internodes. Xerophytes show many adaptations to check the rate of transpiration. Reduction of leaf size, early leaf fall, formation of scale leaves, spines, thorns, thick cuticle, presence of fewer stomata are some of the xerophytic characters. In such cases, the stems become flattened to carryout photosynthesis. These modified stems are called phylloclades. Usually the phylloclades retain water in the form of mucilage. e.g., *Opuntia*, *Casuarina*, *Cocoloba* and *Ruscus*.

In *Opuntia*, the leaves are modified into spines and the stems become fleshy leaf like phylloclade. In *Casuarina* the leaves are modified into scales. The phylloclade in *Ruscus* is leaf like and bear flowers. In *Cocoloba*, after the modification of leaves into scales the stem becomes ribbon like phylloclade with distinct nodes and internodes.



(4) **Cladodes** : These are modifications of stem and branches of limited growth. It has one internode only. Each cladode is green, flat or cylindrical, leaf like structure which performs photosynthesis. In *Asparagus*, the leaves are reduced to curved spines. In *Ruscus aculeatus*, the leaf like cladode are borne in the axils of scale leaves.

(5) **Thalamus** : Thalamus of a flower is a modified stem apex. The other floral parts (sepals, petals, stamens and carpels) are born on the thalamus. It may be convex (*Ranunculus*), concave (*Lathyrus*) or flask shaped (*Rosa*)

## Stem branching

In angiosperms, always the branches are produced by the growth of axillary buds or lateral buds. This type of branching is known as lateral branching. The lateral branching is classified into two kinds racemose and cymose.

(1) **Racemose branching** : In this type of branching, the terminal (or apical) bud of the main stem grows indefinitely and the axillary buds grow out into lateral branches in acropetal succession.

This type of branching is also called monopodial branching. Due to monopodial branching the shoot system of plant appears conical e.g., *Eucalyptus*, *Polyalthia* (Ashoka tree).

(2) **Cymose branching** : In cymose branching the terminal bud is active for a short period and becomes modified into some permanent structures like tendrils, thorns of flowers etc. Due to the terminal bud modification the growth of the main stem is definite. This is also called sympodial branching. Further growth in the plant is carried by one or more axillary buds. Cymose branching may be of three types :

(i) **Uniparous or Monochasial type** : In uniparous type of branching only one lateral branch is produced at each time below the modified terminal bud. Here the successive lateral branches that are formed unite to form a stem. Such a stem is called false axis or sympodium. The uniparous branching is of two kinds, helicoid and scorpioid.

(a) **Helicoid branching** : If the successive lateral branches develop on one side it is called helicoid branching. e.g., *Saraca*, *Canna* and *Terminalia*.

(b) **Scorpioid branching** : If the successive lateral branches develop on either side alternately, it is called scorpioid branching. e.g., *Cissus*, *Gossypium* and *Carissa*.

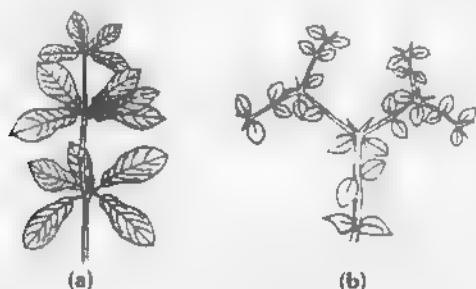


Fig : 2.1-8 Types of uniparous branching  
(a) Helicoid type branching in *Terminalia*  
(b) Scorpioid type branching in *Carissa*

(ii) **Biparous or Dichasial type** : When the activity of terminal bud stops, further growth of plant takes place by two lateral branches, e.g., *Viscum* (Mistletoe), *Silene*, *Stellaria*, *Mirabilis jalapa* (Four O' clock), *Dianthus* (Pink), *Carissa carandas* (Karonda), etc.

(iii) **Multiparous or Polychasial type** : When the activity of terminal bud stops, further growth of plant takes place by a whorl of three or more axillary branches. The axis is said to be multipodial, e.g., *Euphorbia tirucalli*, *Croton*, *Nerium odoratum* (Oleander).

## Buds

A bud is a compact undeveloped young shoot consisting of a shoot apex, compressed axis and a number of closely overlapping primordial leaves arching over the growing apex. Buds which develop into flower are called floral buds.

**Nature of buds** : According to nature they are of following types :

(1) **Vegetative buds** : These buds grow to form only leafy shoots

(2) **Floral buds** : These buds grow to form flowers.

(3) **Mixed buds** : They produce both vegetative and floral branches

**Position of buds** : They are of following types :

(1) **Normal buds** : These buds are borne on stems either terminally or laterally. Since they are borne in normal positions, they are called normal buds.

**Apical buds** : They are borne at the apex of the main stem or a branch. They are also called terminal buds. *Cabbage* is a large apical bud

**Lateral buds** : The buds, which are borne in any other place except at the apices of main stem and its branches, are called lateral buds

(i) **Axillary buds** : The buds develop in the axil of leaves and produces branches.

(ii) **Accessory buds** : They are additional buds borne at the leaf bases. Accessory buds are of two kinds.

(a) **Collateral buds** : Present on the side of axillary bud e.g., lilies

(b) **Superposed buds** : Present above the axillary bud e.g., *Aristolochia*.

(iii) **Extra-axillary Buds** : These buds develop on the node but outside the leaf base.

(vi) **Adventitious buds** : When a bud grows from a position other than normal, it is called adventitious bud. Adventitious bud may be :

(a) **Foliar buds** : Appearing on leaves e.g., in *Bryophyllum*, *Begonia*, *Kalanchoe*.

(b) **Radical buds** : Developing on roots e.g., *Ipomea batatus* (sweet potato), *Dalbergia*

(c) **Cauline buds** : Developing on stem e.g., rose.

**Bulbils or Specialised buds** : Modification of whole buds into swollen structures due to storage of food materials are called bulbils. e.g., In *Lilium bulbiferum* and *Dioscorea bulbifera*, the bulbils develop in axil of leaves; in *Agave*, floral buds of inflorescence transform into bulbils; in *Oxalis*, they develop just above the swollen roots.

## The leaf

The leaf is a green, flat, thin, expanded lateral appendage of stem which is borne at a node and bears a bud in its axil. It is exogenous in origin and develops from the leaf primordium of shoot apex. The green colour of leaf is due to presence of the photosynthetic pigment – chlorophyll which helps plants to synthesize organic food. The green photosynthetic leaves of a plant are collectively called foliage.

### Characteristics of leaf

- (1) The leaf is a lateral dissimilar appendage of the stem.
- (2) A leaf is always borne at the node of stem.
- (3) The growth of leaf is limited.
- (4) The leaves do not possess any apical bud or a regular growing point.

### Parts of a typical leaf

The leaf consists of three parts namely, leaf base (usually provided with a pair of stipules), petiole and leaf blade or lamina.

(1) **Leaf base (Hypopodium)** : Leaf base is the lower most part of the leaf meant for attachment. It acts as a leaf cushion. Some times leaf base shows different variations as follows :

(i) **Pulvinus leaf base** : In members of leguminosae the leaf base is swollen. Such swollen leaf bases are called pulvinus leaf bases as seen in mango leaves. It helps in seismonastic movements (e.g., *Mimosa pudica*) and nyctinastic movements (e.g., *Enterobium*, *Arachis*, *Bean*).

(ii) **Sheathing leaf base** : In grasses and many monocots, the leaf base is broad and surrounds the stem as an envelope, such a leaf base is called sheathing leaf base. e.g., *Sorghum*, *Wheat* and *Palms*. In grasses (*Sorghum*, *Wheat* etc.) the sheathing leaf base protects the intercalary meristem.

(iii) **Amplexicaul** : Leaf base completely encircles the stem. e.g., *Polygonum*.

(iv) **Modified leaf base** : The leaf bases in few plants perform accessory functions and show modifications. In *Allium cepa* (Onion), the leaf bases store food materials and become fleshy. In *Platanus* and *Robinia*, the leaf bases protect the axillary buds and grow around them to form cup like structures.

(v) **Stipule** : The stipules are the small lateral appendages present on either side of the leaf base. They protect the young leaf or leaf primordia. Leaves with stipules are called stipulate and those without them are called exstipulate. The stipules are commonly found in dicotyledons. In some grasses (Monocots) an additional outgrowth is present between leaf base and lamina. It is called ligule. The leaves having ligules are called ligulate.

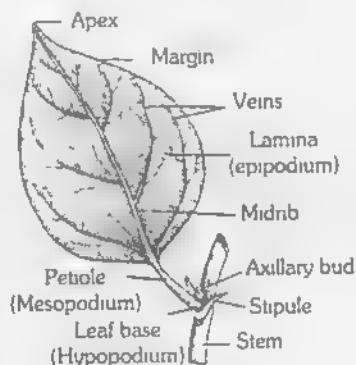


Fig : 2.1-9 Part of a typical leaf

**Types of stipules** : Depending upon the structure and position various kinds of stipules are recognized.

**Free lateral stipules** : A pair of freely arranged stipules present on either side of the leaf base are called free lateral stipules, e.g., *Hibiscus* and *Cotton*.

**Adnate stipules** : The two stipules that fuse with the leaf base or petiole on either side are called adnate stipules, e.g., *Arachis* and *Rose*.

**Inter petiolar stipules** : Stipules present in between the petioles of opposite leaves, e.g., *Ixora* and *Hamelia*.

**Axillary stipules** : Stipules present in the axil of a leaf are called axillary stipule. These are also called intrapetiolar stipule, e.g., *Tabernaemontana* and *Gardenia*.

**Ochraceous stipules** : Membranous tubular stipules that ensheath the axillary bud and a part of internode is called ochraceous stipule. It is formed by the union of two stipules, e.g., *Polygonum* and *Rumex*.

**Hairy stipules** : These are hair like stipules which are dry in nature, e.g., *Anacamptora*.

**Follicaceous** : Green, expanded, leaf like stipules are called follicaceous stipules. They carryout photosynthesis, hence called assimilatory stipules, e.g., *Pisum sativum* and *Lathyrus aphaca*.

**Spinous** : In some plants the stipules are modified into hard, pointed defensive organs called spines, e.g., *Acacia arabica*, *Prosopis juliflora* and *Zizyphus*.

**Convolute or Bud scales** : Scales which protect the buds are called bud scales. Sometimes they are modified into stipules. The bud scales fall off as the buds open, e.g., *Artocarpus* and *Ficus*.

(2) **Petiole (Mesopodium)** : A petiole or leaf stalk is a cylindrical or sub cylindrical structure of a leaf which joins the lamina to the base. A leaf with a petiole is called petiolate and the one without it is called sessile.

### Modification of petiole

**Winged petiole** : Green, flattened petioles may be called winged petioles, e.g., *Citrus* and *Dionaea*.

**Tendrillar petiole** : In few plants the petioles are modified into tendrils and helps the plant in climbing. e.g., *Clematis* and *Tropaeolum*.










**Leaf like petiole (Phyllode)** : A modified petiole which is flat, green and lamina like is called phyllode. It is a photosynthetic organ. e.g., *Acacia auriculaeformis* (Australian babool).

**Swollen or Spongy petiole** : Sometimes the petiole becomes swollen and spongy due to the development of aerenchyma. This type of petioles encloses much air and helps the plant to float. It is a hydrophytic adaptation e.g., *Trapa bispinosa* and *Eichhornia*.








**Spinous petiole** : In few plants, the leaf blades fall off and the petioles become hard and spinous e.g., *Quisqualis* (Rangoon creeper).

(3) **Lamina (Epipodium)** : The green expanded portion of the leaf is called the lamina. It performs vital functions like photosynthesis and transpiration.









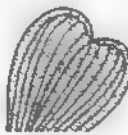

**Shape of lamina :** It varies in different plants as follows.

<p>(1) <b>Acicular type</b> Needle shaped leaves. e.g., <i>Allium cepa</i>, <i>Pinus</i></p>  <p style="text-align: center;"><i>Pinus</i></p>	<p>(2) <b>Linear type</b> Long and slightly broader leaves. e.g., <i>Triticum</i> (wheat), <i>Oryza sativa</i></p>  <p style="text-align: center;"><i>Grass</i></p>
<p>(3) <b>Lanceolate type</b> Lance shaped leaves. e.g., <i>Nerium</i>, <i>Polyalthia</i>.</p>  <p style="text-align: center;"><i>Nerium</i></p>	<p>(4) <b>Orbicular or Rotund type</b> More or less circular leaves. e.g., <i>Lotus</i>, <i>Nasturtium</i></p>  <p style="text-align: center;"><i>Lotus</i></p>
<p>(5) <b>Elliptical oval type</b> Leaves are like an ellipse. e.g., <i>Psidium</i> (Guava), <i>vinica</i></p>  <p style="text-align: center;"><i>Vinca</i></p>	<p>(6) (i) <b>Ovate type</b> Egg or top shaped leaves. e.g., <i>China rose</i> (ii) <b>Obovate type</b> Inverted egg shaped. e.g., <i>Juglans regia</i> (Walnut), <i>Prunus amygdalus</i> (badam)</p>  <p style="text-align: center;"><i>Hibiscus</i></p>
<p>(7) <b>Spathulate</b> Spoon like leaves. e.g., <i>Drosera</i>, <i>Calandula</i></p>  <p style="text-align: center;"><i>Euphorbia</i></p>	<p>(8) <b>Oblique type</b> Leaf lamina is with unequal half. e.g., <i>Margosa</i></p>  <p style="text-align: center;"><i>Margosa</i></p>
<p>(9) <b>Oblong type</b> Rectangular leaves. e.g., <i>Banana</i></p>  <p style="text-align: center;"><i>Banana</i></p>	<p>(10) <b>Reniform type</b> Kidney shaped leaves. e.g., <i>Hydrocotyle</i></p>  <p style="text-align: center;"><i>Hydrocotyle</i></p>
<p>(11) (i) <b>Cordate type</b> Heart shaped (with a deep notch at the base) leaves. e.g., <i>Betel</i>, <i>Banyan</i> (ii) <b>Obcordate type</b> Inverted heart shaped. e.g., <i>Oxalis</i>, <i>Bauhina</i></p>  <p style="text-align: center;"><i>Betel vine</i></p>	<p>(12) <b>Sagittate type</b> Leaves shaped like an arrow head. e.g., <i>Sagittaria</i></p>  <p style="text-align: center;"><i>Sagittaria</i></p>
<p>(13) <b>Hastate type</b> Leaves like sagittate but the two basal lobes are directed outwards. e.g., <i>Ipomoea</i>.</p>  <p style="text-align: center;"><i>Ipomoea</i></p>	<p>(14) <b>Lyrate type</b> Leaves shaped like a lyre. e.g., <i>Raphanus sativus</i> (Raddish), <i>Brassica campestris</i> (mustard)</p>  <p style="text-align: center;"><i>Mustard</i></p>
<p>(15) <b>Centric type</b> Hollow and cylindrical leaves. e.g., <i>Onion</i></p>  <p style="text-align: center;"><i>Onion</i></p>	<p>(16) <b>Cuneate type</b> Wedge shaped leaves. e.g., <i>Pistia</i></p>  <p style="text-align: center;"><i>Pistia</i></p>

**Margin of lamina :** The margin of the lamina may be of different types as given

Entire	Serrate	Repand	Dentate	Crenate	Spiny	Biserrate
Leaves with smooth margin.	Leaves have saw like margin.	Leaves have wavy margin.	Leaves have large pointed teeth like margin.	Leaves have round teeth margin.	Leaves have spiny margin.	Margins have incisions which are further incised.
						
Mango	Hibiscus	Polyalthia	Aloe	Bryophyllum	Argemone	Ricinus

**Apex of lamina :** The apex of the leaf lamina shows variations in different plants.

<b>(1) Acute</b> The apex is narrow and pointed. e.g., Mango. China rose 	<b>(2) Acuminate</b> The apex is drawn out into a long tapering tail. e.g., Ficus religiosa. 
<b>(3) Obtuse</b> The apex is rounded. e.g., Banyan. 	<b>(4) Mucronate</b> Round apex with sharp pointed tip. e.g., Vinca. 
<b>(5) Cuspidate or Spiny</b> The apex is spinous. e.g., Date palm. 	<b>(6) Tendrillar</b> The apex form a tendril. e.g., Gloriosa. 
<b>(7) Cirrhose</b> The mucronate like apex ends with fine thread like structure. e.g., Banana. 	<b>(8) Truncate</b> The shape is abruptly cut across. e.g., Paris polyphylla. 
<b>(9) Retuse</b> The apex obtuse is partial e.g., Pistia 	<b>(10) Emarginate</b> The obtuse apex is deeply notched. e.g., Bauhinia, Oxalis 

**Surface of lamina :** The surface of the lamina may be of many kinds.

**Glabrous :** Smooth and without hair. e.g., Mangifera indica.

**Glaucus :** Covered by waxy coating with white tinge. e.g., Calotropis.

**Scabrous :** Rough surface e.g., Ficus

**Viscose** : Sticky surface. e.g., *Cleome*.

**Pubescent** : Covered with soft and wooly hair. e.g., *Tomato*.

**Pilose** : Covered with long distinct scattered hair. e.g., *Grewia pilosa*.

**Hispid** : Covered with long rigid hair. e.g., *Cucurbita*.

**Spinose** : Covered with small spines. e.g., *Solanum xanthocarpum*.

**Texture of lamina** : The texture of lamina also varies in different species.

**Herbaceous** : When the lamina is thin and soft

**Coriaceous** : When the lamina is leathery.

**Succulent** : When the lamina is thick, soft and juicy.

**Hygrophytic** : When the lamina is very thin, membranous and spongy.

#### Life Span or Duration

(i) **Caducous** (Fugacious) : Leaves falling down soon after their appearance, e.g., *Opuntia* (vern. Chhittar Thor).

(ii) **Deciduous or Annual** : Leaves falling off almost simultaneously at the end of growing season. The phenomenon is called **leaf fall**, e.g., *Mulberry*, *Poplar*. In *Euphorbia royleana* the leaves are **drought deciduous**.

(iii) **Persistent (evergreen)** : Leaves live for more than one season. They fall down individually at different times. Plants look evergreen, e.g., *Pinus*, *Eucalyptus*, *Mango*, *Oleander*

#### Leaf Insertion

(i) **Radical** : Leaves borne on a reduced stem and appear to arise directly from the top of the root, e.g., *Radish*, *Turnip*

(ii) **Cauline** : Leaves found on the nodes of the main stem, e.g., *Maize*, *Rose*, *Althaea*.

(iii) **Ramal** : Leaves produced on the nodes of the stem branches, e.g., *Dalbergia*, *Peepal*, *Zizyphus*.

#### Types of leaves

On the basis of shape of lamina, the leaves are classified into two types, namely, simple leaf and compound leaf.

(1) **Simple leaves** : The leaf having single undivided lamina is called the simple leaf. The simple leaf may be entire (e.g., *Mango* and *Hibiscus rosa sinensis*) or lobed. The lobes of a simple leaf may be entire pinnately arranged (e.g., *Brassica*) or palmately arranged (e.g., *Gossypium*, *Passiflora* and *Ricinus*)

(2) **Compound leaves** : A compound leaf is one in which the lamina or the leaf blade is completely divided into many segments or units called leaflets or pinnae. When pinnae of leaflets are attached in various ways to the portion of leaf axis known as the rachis. The compound leaves may be of two types, namely, pinnate compound leaves and palmate compound leaves.

(i) **Pinnate compound leaves** : It is the most familiar and widespread type of compound leaf in which the rachis is elongated and bears two rows of simple or divided leaflets. The leaflets may be arranged alternately or in pairs along with the rachis. It is of following types :

**Unipinnate compound leaf** : Here the primary rachis is unbranched and bears leaflets on either side. Unipinnate leaves are of two types :

**Paripinnate** : The unipinnate leaf with even number of leaflets. They are borne in pairs. e.g., *Tamarindus indica* (Imli), *Cassia* etc.

**Imparipinnate** : The unipinnate leaf with odd number of leaflets. The rachis is terminated by single unpaired leaflet. e.g., *Neem*, *Rose*, *Murraya*.

**Bipinnate compound leaf** : In this type, the primary rachis is divided once and produces secondary rachis. The leaflets develop on the secondary rachis. e.g., *Delonix* and *Acacia*, *Mimosa pudica*, *Albizia* (sub family mimosoideae).

**Tri-pinnate compound leaf** : In this type the primary rachis divides twice and produces secondary and tertiary rachis. The leaflets develop on the tertiary rachis. e.g., *Moringa* (Soanajana) and *Millingtonia*.

**Decomound leaf** : Here the primary rachis divides many times without any definite order. The lamina is dissected into many units. e.g., *Coriandrum*, *Carrot* etc.

(ii) **Palmate compound leaf** : In a palmately compound leaf, the leaflets are arranged at the tip of the petiole. According to the number of leaflets present at the tip of the petiole. These leaves are of following types :

**Unifoliate** : In this case, a palmately compound leaf is reduced to a single terminal leaflet. e.g., *Citrus* (Khatta), *Lemon*, etc.

**Bifoliate** : This type of leaf has only two leaflets attached side by side at the tip of petiole, e.g., *Balanites roxburghii*, *Hardwickia binata*, etc.

**Trifoliate** : This type of leaf has three terminal leaflets, *Aegle marmelos* (Wood apple, Vern. Bael), *Oxalis corniculata*, *Trifolium* (Clover), etc. These leaves differ from trifoliate imparipinnate (e.g., *Lablab*) in having all the three leaflets attached at the tip of petiole.

**Quadrifoliate** : This leaf has four leaflets attached to the tip of petiole. e.g., *Paris quadrifolia*, *Marsilea*.

**Multifoliate (Digitate)** : A palmately compound leaf having five or more terminal leaflets, e.g., *Bombax malabarica*, *Cleome viscosa*, *Gynandropsis pentaphylla*, etc.

#### Phyllotaxy (Phyllotaxis)

The arrangement of leaves on the stem is called phyllotaxy (Gk. Phyllon = leaf; taxis = arrangement)

(1) **Alternate or Spiral phyllotaxy** : When only one leaf is found at each node. The leaves present at successive nodes alternate with each other. The arrangement is said to be alternate or spiral. The leaves are commonly arranged spirally around the stem. In spiral phyllotaxy, the leaves are arranged on the stem in regular vertical row. Such rows are called orthostichies. In practice the angular divergence is determined in the following manner :

$$\text{Angular divergence} = \frac{\text{No. of circles}}{\text{Orthostichies}} \text{ of a circle i.e., } 360^\circ$$

A phyllotaxy is written by taking the number of spirals (circles) as numerator and the number of leaves as denominator. Based on the number of orthostichies seen on the stem, the spiral phyllotaxy may be described as given under.

**Distichous or 1/2 Phyllotaxy :** Where the angular divergence is 1/2 of 360° i.e., 180°. e.g., *Ravenella*.

**Tristichous or 1/3 Phyllotaxy :** Where the angular divergence is 1/3 of 360° i.e., 120°. e.g., Moss, *Cyperus rotundus*.

**Pentastichous or 2/5 Phyllotaxy :** Where the angular divergence is 2/5 of 360° i.e., 144°. e.g., China rose

**Octastichous or 3/8 Phyllotaxy :** Where the angular divergence is 3/8 of 360° i.e., 135°. e.g., *Carica papaya*.

In these types, if one adds up two preceding numerators and denominators, a series is formed called Schimper-Brown Series.

$$\text{e.g., } \frac{1}{2}, \frac{1}{3}, \frac{1+1}{2+3} = \frac{2}{5}, \frac{1+2}{3+5} = \frac{3}{8}, \frac{2+3}{5+8} = \frac{5}{13}, \text{ and so on.}$$

(2) **Opposite phyllotaxy :** When two leaves are present at a node opposite to each other the type of phyllotaxy is called opposite. It is of two types :

(i) **Opposite superposed :** All the pair of leaves of a branch arise in the same plane so that only two vertical rows of leaves are formed. e.g., Jamun, Guava, etc.

(ii) **Opposite decussate :** A pair of leaves at one node stands at right angle to the next upper or lower pair so that four vertical rows are formed on the stem. e.g., *Calotropis*, *Zinnia*, Tulsi, *Quisqualis*.

(3) **Whorled phyllotaxy :** If more than two leaves are present at a node as whorl, it is called whorled phyllotaxy. It is also called cyclic or verticillate phyllotaxy. e.g., *Nerium*, *Hydrilla* and *Alstonia*.

(4) **Leaf mosaic :** This is a special type of arrangement of leaves. Older leaves present at the lower nodes of the stem possess longer petioles with bigger lamina and the young leaves of upper nodes bear shorter petioles with smaller lamina. e.g., *Begonia*, *Acalypha* and *Sycamore*.

### Vernation (Aestivation)

Arrangement of leaves in bud condition is known as vernation e.g., Imbricate (irregular overlapping), contorted (twisted, regular overlapping of margins), induplicate (margin bent inwardly), equitant (conduplicate in two series, one overlapping the other completely), half equitant, supervolute (convolute leaves, one rolled over other).

### Heterophylly

It is the occurrence of more than one type of leaves on the same plant. Heterophylly is of four types :

(1) **Adaptive heterophylly :** Submerged leaves are different from floating and emerged leaves of the same plant due to different adaptations. e.g., *Limnophila*, *Heterophylla*, *Sagittaria*, *Ranunculus aquatilis*. The emerged leaves are broad and fully expanded while the submerged leaves are narrow, ribbon shaped, linear or highly dissected.

(2) **Environmental heterophylly :** The heterophylly is due to change in environment including soil, temperature, humidity and air currents. e.g., *Sagittaria*.

(3) **Developmental heterophylly :** Young leaves are different from mature leaves, e.g., *Eucalyptus*.

(4) **Habitual heterophylly :** Leaves of different shape and incisions occur at the same time, e.g., Jack fruit tree (*Artocarpus heterophyllus*), *Ficus heterophylla*, *Hemiphragma heterophyllum*, *Broussonetia papyrifera*. In *Hemiphragma*, the main stem bears ovate and entire leaves while branches possess acicular leaves.

### Modification of leaves

**Leaf tendrils :** The leaves are modified into slender wiry and coiled structures called leaf tendrils. The tendril may be formed by entire leaf or a part of the leaf.

Entire leaf modified into tendril, e.g., *Lathyrus aphaca* (Wild pea).

Terminal leaflets modified into tendril, e.g., *Pisum sativum* (Pea), *Lathyrus odoratus* (Sweet pea), *Narvelia*.

Leaf tip modified into tendril, e.g., *Gloriosa*.

Petiole modified into tendril, e.g., *Clematis*.

Stipule modified into tendril, e.g., *Smilax*.

Midrib modified into tendril, e.g., *Nepenthes*.

**Spines :** A pointed structure formed by the modification of entire leaf or part of a leaf is called a spine. Different part of a leaf or entire leaf may be modified into spines. e.g., In *Opuntia* leaves of axillary branches are modified into spines.

In *Berberis* entire leaf is modified into three spines. In *Phoenix* leaf tip is modified into spine. In *Citrus* first leaf of axillary branch modified into spine. In *Argemone* leaf margin is modified into spine. In *Perkinsonia*, *Acacia* and *Zizyphus* stipules are modified into spines.

**Scale leaves :** In many xerophytes, the foliage leaves are reduced to scale leaves. They are thin, membranous, dry, small, sessile, colourless structures. e.g., *Casuarina*, *Orobancha* and *Balanophora*.

**Phyllode :** It is a green, expanded structure formed by the modification of petiole or rachis of leaf. Many xerophytes reduce the size of their leaves to minimize water loss. Such plant develop phyllodes to carryout photosynthesis e.g., *Acacia*, *Melanoxylon* and *Parkinsonia*.

**Storage leaves :** Leaves become fleshy due to storage of water or food materials. Such leaves are called storage leaves. They are usually found in succulent plants. In plants like *Aloe*, *Allium*, *Kalanchoe* and *Peperomia*.

**Reproductive leaves :** In some plants the vegetative propagation is carried out by the production of epiphyllous buds on leaves. Such leaves are called reproductive leaves. The epiphyllous buds when come in contact with soil develop into new plants.

**Absorbing leaves :** In some rootless, aquatic plants, the submerged leaves are modified into root like structure to absorb water and mineral salts. Such modified leaves are called absorbing leaves. e.g., *Utricularia*.

**Floral leaves :** Floral parts such as sepals, petals, stamens and carpels are modified leaves. Sepals and petals are leafy stamens are considered pollen bearing microsporophylls and carpels are ovule bearing megasporophylls.

**Cotyledons :** The mature embryo shows either one (monocotyledons) or two cotyledons (dicotyledons). *Cuscuta*, a

parasite is included in dicotyledon. However it has no cotyledon and many cotyledons, as in gymnosperms. These cotyledons are considered as embryonic leaves which are the first leaves of a shoot system.

**Trap leaves :** The trap leaves are also called insectivorous leaves or carnivorous leaves. Plants having trap leaves usually grow in nitrogen-deficient soils (boggy soils). They have poorly developed root system.

These plants get their nitrogenous requirement by capturing the insects. To attract, capture, kill and digest the insects, the leaves are modified into trap leaves. e.g., *Nepenthes*.

**Leaf Bladders :** Some of the leaf segments of aquatic insectivore, *Utricularia*, are modified into bladders for trapping small aquatic animals like *Cyclops*.

**Leaf Pitcher :** Lamina (e.g., *Nepenthes*) or whole leaf (e.g., *Dischidia*, *Sarracenia*) is modified into pitcher. Pitcher has lid and takes part in catching and digesting small animals in *Nepenthes* and *Sarracenia*. In *Dischidia* the pitcher stores rain water.

**Leaf Fall or Leaf Abscission :** It is the shedding of leaves. A special layer of parenchymatous cell appears at the base of leaf. The same is called abscission or separation layer. A layer of suberised thick walled cells (cork cells) is formed below it. It is protective layer. The cells of abscission layer gelatinise and the leaf falls leaving a scar.

## Venation

The arrangement of veins in the lamina of a leaf is called venation. The veins are the hard structures consisting of xylem and phloem. The veins give mechanical strength and shape to the lamina. Angiosperms exhibit two types of venation.

### (1) Reticulate venation

In this type, the lateral veins divide and redivide to form many veinlets. These veinlets are arranged in a net like fashion or reticulum. Reticulate venation is the characteristic feature of dicotyledons. But exceptionally some monocotyledons also show reticulate venation. e.g., *Smilax*, *Alocasia* and *Dioscorea* etc. Reticulate venation is of two types :

(i) **Unicostate or Pinnate venation :** This type of venation is characterized by the presence of a single strong midrib that extends upto the apex of lamina. The midrib produce lateral veins on either side which divide repeatedly. e.g., *Ficus* and *Mangifera*.

(ii) **Multicostate or Palmate venation :** Here more than one prominent veins start from the base of the lamina and proceed upwards.

The lateral veinlets, arising from main veins, form network. Multicostate venation is of two types :

(a) **Convergent :** When the prominent veins converge towards the apex of lamina. e.g., *Zizyphus* and *Cinnamomum camphora* (kapoor), etc.

(b) **Divergent :** When the prominent veins spread out towards the margins. e.g., *Papaya*, *Ricinus*, *Cucurbita* etc.

### (2) Parallel or Striate venation

In this type, veins and veinlets run parallel to each other. Parallel venation is the characteristic feature of monocotyledons.

Exceptionally few dicots show parallel venation, e.g., *Calophyllum* and *Eryngium*. It is of two types :

(i) **Unicostate or Pinnate venation :** The leaf lamina possesses single prominent vein which gives rise to a large number of lateral veins. All the lateral veins run parallel towards margin. e.g., *Banana*, *Canna*, *Curcuma* etc.

(ii) **Multicostate or Palmate venation :** The leaf lamina possesses several prominent veins which run parallel to each other. It is of two types :

(a) **Convergent :** The prominent veins run parallel to each other and converge at the apex. e.g., *Sugarcane*, *Maize*, *Wheat*, *Bamboos* and *Grasses*.

(b) **Divergent :** All the prominent veins of leaf lamina spread out towards the margin. e.g., *Fan palm*.

**Ptyxis :** Folding of lamina in bud condition is called ptyxis – circinate (rolled from apex to base, e.g., fern leaves), **plicate** (plaited, folded lengthwise like Japanese fan, e.g., *Fan Palm*), **conduplicate** (folded over midrib, e.g., *Bauhinia*, *Guava*), **reclinate** (upper half bent over lower half e.g., *Loquat*), **crumpled** (irregular folding, e.g., *Cabbage*), **involute** (margins rolled on upper surface, e.g., *Colocasia*), **revolute** (margins rolled on lower surface, e.g., *Oleander*).

## Inflorescence

The flowers are arranged in some definite manner on the plant in each species of the flowering plants. The mode of arrangement of flowers on a specialised branch on top of the plant which bears flowers is called inflorescence. The stalk of the inflorescence is called peduncle.

(1) **Solitary flowers :** They are those flowers which are not grouped into inflorescence but occur singly. Solitary flowers are of two types :

(i) **Solitary terminal :** Single terminal flowers develop on the tip of main stem and its branches, e.g., *Poppy*

(ii) **Solitary axillary :** Flower occurs singly in the axil of a leaf (e.g., *Petunia*) or tip of a peduncle (e.g., *China Rose* = *Shoe Flower* = *Hibiscus rosa-sinensis*).

(2) **Racemose Inflorescence :** An inflorescence of indefinite or indeterminate growth having lateral or axillary flowers borne acropetally (oldest at base and youngest at apex). Different types of racemose inflorescence are as follows :

### (a) Simple Racemose Inflorescence

(i) **Typical Raceme (= Raceme) :** Unbranched, elongated peduncle bearing pedicellate or stalked flowers acropetally, e.g., *Delphinium* (Larkspur), *Raphanus* (Radish), *Linaria*, *Lupinus*.

(ii) **Corymb :** All the acropetally arranged flowers come to lie at the same level due to slight shortening of peduncle and slight elongation of pedicels of lower flowers, e.g., *Iberis*, *amara* (Candytuft).

(iii) **Corymbose-Raceme :** Like a corymb near the growing point and raceme lower down though the pedicels of the lower flowers are longer, e.g., *Brassica compastris* (Mustard).



(iv) **Umbel** : Pedicellate flowers arranged centripetally around an extremely reduced peduncle with an involucre below, e.g., *Centella* (= *Hydrocotyle*) *asiatica* (Brahmi Booti), *Androsace*.

(v) **Spike** : Sessile (i.e., without stalk) flowers borne acropetally, e.g., *Callistemon* (Bottle Brush), *Amaranthus*, *Achryanthes*, *Adhatoda*.

(vi) **Spikelet** : It is a compact spike having a few flowers borne on axis called **rachilla** and surrounded by two **scales** (= bracts) called **glumes**, e.g., Wheat, Oat, Sorghum, Grass.

(vii) **Strobile** : It is a spike having persistent and membranous bracts, e.g., *Humulus* (Hop).

(viii) **Catkin** : Compact unisexual spike often hanging, e.g., *Morus* (Mulberry), *Salix* (Willow), *Populus* (Poplar), *Betula* (Birch), *Acalypha*, *Quercus* (Oak).

(ix) **Spadix** : A fleshy spike covered with spathe is called spadix, e.g., maize, banana etc.

(x) **Capitulum** (Racemose Head, Anthodium) : Peduncle is flattened to form **receptacle** that bears centripetally arranged sessile flowers or florets surrounded by involucre of bracts, e.g., *Cosmos*, *Zinnia*, *Tagetes*, *Chrysanthemum*, *Sonchus*, *Ageratum*. Florets may be tubular or ligulate. Capitula may be **homogamous** (with one type of florets e.g., only ligulate in *Sonchus* or *Zinnia* and only tubular in *Vernonia* or heterogamous (with two type of florets). Sunflower (*Helianthus annuus*) is heterogamous with both ligulate female **ray florets** and tubular intersexual **disc florets**.

#### (b) Compound Racemose Inflorescence

(i) **Raceme of Racemes** (= **Compound Raceme** = **Panicle**) : Racemes are borne acropetally on a raceme, e.g., *Cassia fistula*, *Delonix regia*, (Gold Mohar), *Caesalpinia* (Gulmohar), *Yucca*, *Asparagus*, *Asphodelus*, *Margosa*.

(ii) **Corymb of Corymbs** (= **Compound Corymb**) : An axis bearing a number of corymbs in a corymbose fashion, e.g., *Pyrus*, Cauliflower. Marketed Cauliflower (*Brassica oleracea* var. *botrytis*) represents an undeveloped inflorescence.

(iii) **Umbel of Umbels** (= **Compound Umbel**) : Many umbels develop from a common point in an umbellate fashion. It is characteristic of family *Umbelliferae*. Involucre (below mother umbel) and involucels (below each umbellule) may be present, e.g., Coriander, Fennel, Carrot, Cumin

(iv) **Spike of Spikes** : e.g., *Amaranthus spinosus*.

(v) **Spike of Spikelets** : e.g., Wheat

(vi) **Spadix of Spadices** (**Compound Spadix**) : e.g., Date Palm, Coconut

(vii) **Capitulum of Capitula** : e.g., *Echinops*.

(viii) **Panicle of Spikelets** : e.g., Jowar, Rice, Oat.

(3) **Cymose Inflorescence** : A more or less flat topped, broad inflorescence of determinate growth or definite growth. Where central flower opens first (i.e., central flower is most mature). Here the main axis terminates in a flower.

(a) **Uniparous or Monochasial Cyme** : The flowering axis is **sympodial**. As the growing point ends in a flower, further growth is continued by a lateral branch which also ends in a flower. The process is repeated

(i) **Helicoid Uniparous** : The flowers are borne on one side e.g., *Begonia*, *Drosera* (sundew). It can be **drepanium** (flower in one plane) or **bostryx** (flower in different planes).

(ii) **Scorpioid Uniparous** : The flowers are borne on both sides alternately, e.g., *Tecoma*, *Freesia*, *Heliotropium*, *Rhipidium* is scorpioid cyme having all the flowers in one plane (e.g., *Solanum nigrum*) while in *cincinnus* the flowers are borne in different planes.

Solitary axillary flower of China Rose is also considered to be single flowered uniparous cyme.

(b) **Biparous or Dichasial Cyme** : Growth of the flowering axis is continued by two branches when the growing point of the parent axis is changed into a flower, e.g. *Dianthus* (Pink), *Silene*, *Nyctanthes*, *Jasminum*, *Clerodendron*, *Bougainvillea*, Teak. Arrangement of flowers is either **basipetal** (if axis elongated) or **centrifugal** (if axis short).

(c) **Multiparous or Polychasial Cyme** : More than branches continue growth of the flowering axis when the parent axis is changed into a flower, e.g., *Calotropis*, *Hamelia*, *Asclepias*, Arrangement of flowers is generally centrifugal.

(d) **Cymose Head** : A number of centrifugally arranged flowers are borne around a receptacle, e.g., *Anthocephalus cadamba* (Kadam). *Acacia*, *Mimosa* and *Albizia* also possess such an inflorescence but it is now considered to be **capitate** or **spikate head** due to centripetal arrangement of flowers.

(e) **Scapigerous Cyme Umbel** : In Onion, a scape bears and umbellate cyme covered by one or more spathes.

#### (4) Mixed Inflorescence

(i) **Thyrus (Thyrse)** : Cymose clusters arranged acropetally, e.g., *Vitis vinifera* (Grape Vine).

(ii) **Mixed Spadix (Spadix of Cymes)** : Spadices having cymose inflorescence arranged acropetally on fleshy axis, e.g., Banana.

(iii) **Panicle of Spikelets** : Spikelets arranged in a compound raceme, e.g., Oat, Rice.

(iv) **Corymb of Capitula** : e.g., *Ageratum*.

(v) **Other Types** : Like umbel of capitula, cyme of capitula (e.g., *Vernonia*), cyme of umbels (e.g., *Lantana*), cyme of corymbs, etc

#### (5) Special Inflorescence

(i) **Hypanthodium** : It has a flask-shaped fleshy receptacle, a pore or ostiole lined by scales and a short canal bearing hair. Internally the receptacle bears male flowers ostiole, female flowers towards base and sterile female flowers between the two, e.g., *Ficus* (Peepal, Banyan, Fig).

(ii) **Coenanthium** : It has a saucer-shaped receptacle with upturned margin and bearing florets like hypanthodium, e.g., *Dorstenia*.

(iii) **Verticillaster** : It is characteristic inflorescence of *Ocimum* (Tulsi) of family *Lamiaceae* or *Labiatae*. Here flowers are arranged in two opposite cymose groups on each node.

(iv) **Cyathium** : It is characteristic inflorescence of *Euphorbia*, in which single female flower is present in the centre and number of male flowers around it, inside a cup-shaped involucre (whorl of bracts).



## Flower

It can be defined as modified dwarf shoot which is meant for sexual reproduction. It is characteristic feature of angiosperm.

**Parts of a typical flower :** A typical flower of an angiosperm consists of four types of floral parts namely calyx, corolla, androecium and gynoecium.

### General description of a flower

The flowers are termed pedicellate if they possess stalks and sessile if they lack them. The flower may be described as complete if it bears all the floral parts and incomplete, when one or more floral parts are absent. Flowers are called bisexual if they bear both androecium and gynoecium e.g., *Hibiscus*. The unisexual flowers have either androecium or gynoecium. The unisexual flowers may be male flowers or female flowers. The male flower are also called staminate flowers as they have stamens only.

The female flowers have only the carpels and hence called pistillate flowers. Flowers with sterile sex organs are described as neutral flowers. According to the distribution of male, female and bisexual flowers, various patterns are recognized.

**Monoecious :** Presence of male and female flowers on the same plant, e.g., *Acalypha*, *Cocos* and *Ricinus*. In maize flower are unisexual but plant is monoecious.

**Dioecious :** Presence of male and female flowers on different plants, namely, male plants and female plants. e.g., *Cycas*, *Carica papaya* and *Vallisneria*.

**Polygamous :** Presence of unisexual and bisexual flowers on the same plant, e.g., *Mangifera* and *Polygonum*.

### Symmetry of flower

The number, shape, size and arrangement of floral organs in a flower determines its symmetry. On the basis of symmetry flowers can be of the following types :

**Actinomorphic (Regular = Symmetrical) :** Actinomorphic flowers can be divided (passing through center) by any vertical plane into two equal and similar halves. e.g., Mustard, Brinjal, *Catharanthus roseus*.

**Zygomorphic (Monosymmetrical) :** Zygomorphic flowers can be divided into two equal halves by only one vertical division e.g., Pea, Larkspur, *Ocimum*.

**Asymmetrical (Irregular) :** Asymmetrical flowers can not be divided into two equal halves by any vertical division. e.g., *Canna*, *Orchids*.

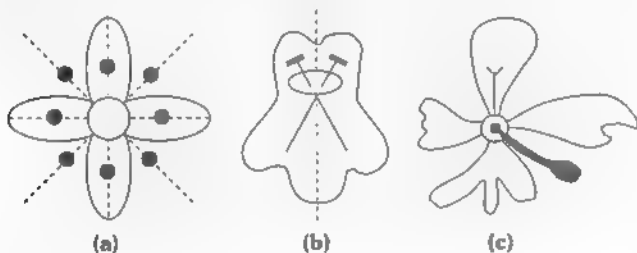


Fig : 2.1-10 Symmetry of flowers (a) Actinomorphic, (b) Zygomorphic, (c) Asymmetrical

### Arrangement of floral organs

On the basis of arrangement of floral organs, three types of flowers are recognized. They are :

**Acyclic :** Here the thalamus is conical or convex and the floral parts are spirally arranged, e.g., Water lily and *Magnolia*.

**Cyclic :** Here the floral organs are arranged in regular whorls at the nodes of the thalamus, e.g., *Hibiscus* and *Datura*.

**Hemicyclic (Spirocyclic) :** Here some floral parts (sepals and petals) are arranged in regular whorls and the remaining parts (stamens and carpels) are arranged spirally. e.g., *Annona* and *Polyalthia*.

Number of floral parts in whorl is called the merosity. There are two kinds of flowers based on the merosity of the flower. They are isomerous flowers and anisomerous flowers.

If the number of sepals, petals, stamens and carpels of flower is equal, such flowers are called isomerous flowers.

**Dimerous :** Two floral parts in each whorl. e.g., Poppy flower.

**Trimerous :** Three floral parts in each whorl. e.g., Monocot flowers (*Liliaceae*).

**Tetramerous :** Four floral parts in each whorl. e.g., Mustard.

**Pentamerous :** Five floral parts in each whorl. e.g., *Solanum*.

### Detailed structure of flower

Angiospermic flowers exhibit many variations in their external morphological characters.

(1) **Bract :** Bract (hypophyll) is a small leaf like structure on the peduncle which produces a flower in its axil. The floral buds are usually protected by the bracts.

Flower with a bract is described as bracteate and the flower without a bract is known as ebracteate. Bracteoles are small scale like structures present on the pedicel. Bracts are modified into following structures :

**Foliaceous bract :** Leaf like, expanded green bract is called the foliaceous bract, e.g., *Pisum*, *Lathyrus*, *Adhatoda* and *Gynandropsis*.

**Spathe :** A large modified bract which encloses spadix inflorescence totally or partially. It may be leathery or woody, e.g., *Alocasia*, *Cocoa*, *Musa* and *Typhonium*.

**Petaloid bract :** Brightly coloured petal like bract is known as petaloid bract, e.g., *Bougainvillea*, *Poinsettia* and *Euphorbia*.

**Involucre :** One or more whorls of green bracts that protect young inflorescence is called involucre, e.g., *Coriandrum*, *Tagetes* and *Heracleum*.

**Epicalyx :** Whorl of bracteoles present below the calyx or outside the calyx, e.g., *Hibiscus rosa sinensis* and *Malva viscosa*.

**Scaly bracts :** Reduced, membranous, scale like bracts seen in head inflorescence, e.g., florets in *Tridax* and *Helianthus*.

**Glumes :** The bracts found on the rachilla of spikelet are called glumes. They may be sterile glumes or fertile glumes (lemma), e.g., *Oryza sativa*.

(2) **Thalamus** : The terminal part of the pedicel is called thalamus or torus or receptacle. It is a condensed axis of the flower from which all floral parts arise. Depending upon the position of gynoecium on the thalamus with respect to other parts, flowers are of three kinds – hypogynous, perigynous and epigynous.

In many flowers, the thalamus is condensed and the internodes are not seen clearly. But there are some flowers with elongated, distinct floral internodes as mentioned below :

**Anthophore** : This is the first elongated internode between the calyx and corolla, e.g., *Silene*, *Pennsylvanica* and *Lychnis*.

**Androphore** : It is the second elongated internode between corolla and androecium, e.g., *Gynandropsis*.

**Gynophore** : It is the third elongated internode between androecium and gynoecium e.g., *Capparis* and *Gynandropsis*.

**Gynandrophore** : It is an elongated stalk like part between non essential and essential organs of the flower. It is equivalent to androphore, e.g., *Passiflora*.

**Carpophore** : This is a stalk like connection present between two carpels. It is formed due to expansion of the thalamus between the carpels, e.g., *Coriandrum* and *Foeniculum*.

**Androgynophore** : When androphore and gynophore are present simultaneously, it is called androgynophore e.g., in *Cleome gynandra* Syn. *Gynandropsis gynandra*.

(3) **Perianth** : The non essential organs, calyx and corolla are together called perianth. The perianth protects the stamens and carpels. In angiospermic flowers, the perianth exists in different forms.

**Achlamydeous** : Perianth is absent and the flowers appear naked. Mostly the achlamydeous flowers occur in cyathium inflorescence. e.g., *Euphorbia*, *Poinsettia*.

**Chlamydeous** : Perianth is present and the flowers usually appear attractive. The chlamydeous flowers are of two types. They are :

Monochlamydeous flowers are with perianth in one whorl, e.g., *Amaranthus* and *Ricinus*.

Dichlamydeous flowers are with perianth differentiated into calyx and corolla. They are arranged in two different whorls. The dichlamydeous condition is of two types :

**Homochlamydeous** : The two whorl or the perianth (calyx and corolla) are similar in all respects and are not identified by different colours, e.g., *Michelia*.

**Heterochlamydeous** : The two whorls of the perianth are dissimilar in many respects. The outer whorl consists of small, green sepals and the inner whorl with large variously coloured petals, e.g., *Datura* and *Hibiscus*. The term "tepals" is used to describe the perianth units when both sepals and petals are similar. e.g., most of the monocots.

(4) **Calyx** : It is the outermost whorl of the flower. It consists of sepals. Usually, the sepals are small and green. They protect other floral organs when the flower is in bud condition. The calyx is described as polysepalous when the sepals are free (e.g., *Annona*, *Tomato*) and gamosepalous when the sepals are united (e.g., *Datura* and *Hibiscus*). If sepals are fused less than half of the length of calyx tube it is called as partite and if the fusion of sepals is very little, just at the base of calyx tube, it is said to be connate. The sepals may be deciduous or persistent.

Usually the persistent calyx do not show any growth after fertilization. Such a calyx is termed as marcescent (e.g., *Brinjal*, *Chilies*). Sometimes the persistent calyx shows continuous growth even after, fertilization. This type of calyx called accrescent (e.g., *Physalis* and *Shorea*).

In some plants a whorl of green sepals like structure is present at the base of calyx called epicalyx. Epicalyx is considered a whorl of the bracteoles and mostly found in the flowers of family *Malvaceae* (*Althaea*, *Cotton*). The calyx may show number of modifications. They are :

**Campanulate** : Bell shaped, e.g., *Althaea*.

**Cupulate** : Cup like, e.g., *Gossypium*.

**Urceolate** : Urn shaped, e.g., *Hyoscyamus*.

**Infundibuliform** : Funnel shaped, e.g., *Atropa belladonna*.

**Tubular** : Calyx tube like, e.g., *Datura*.

**Bilabiate** : Calyx forms two lips, e.g., *Ocimum*.

**Spurred** : One or two sepals forming a beak like structure, e.g., *Larkspur*.

**Pappus** : Calyx are modified into hairs e.g., *Sonchus*, *Tridax* (*Asteraceae/Compositae*).

**Spinous** : When calyx forms spines, e.g., *Trapa*.

**Hooded** : When sepals enlarged to form a hood over the flower, e.g., *Aconitum*.

**Petaloid** : Enlarged and brightly coloured sepals, e.g., *Clerodendron*, *Mussaenda*, *Sterculia*, *Caesalpinia* and *Saraca*.

(5) **Corolla** : It is the second whorl of the flower consisting of petals. Usually the petals are brightly coloured and scented. They attract the insects which act as agents for pollination. The corolla may be polypetalous (with free petals), gamopetalous (with united petals) or apetalous (without petals). The corolla may undergo modifications or possess some special appendages.

**Sepaloid** : Green or dull coloured sepals. e.g., *Annona*, *Polyalthia* and *Artabotrys*.

**Saccate** : The corolla tube may form a pouch on one side. e.g., *Antirrhinum*.

**Spurred** : Sometimes one or two petals or the entire corolla tube grow downwards forming a spur that usually stores nectar. e.g., *Aquilegia vulgaris*.

**Corona** : Special appendages of different kinds like scales, hairs develop from the corolla. Such appendages are called corona. e.g., *Passiflora*, *Oleander* and *Nerium*.

**Forms of corolla** : Both polypetalous and gamopetalous corolla exhibit great variation in their forms. It is of following types :

(i) **Polypetalous corolla** : They are of following types :

**Cruciform** : Four free clawed petals arranged in the form of a cross, e.g., Mustard and Radish.

**Rosaceous** : Five free sessile petals with lobes spreading outwards, e.g., Rose, *Hibiscus*.

**Caryophyllaceous** : Five free clawed petals with limbs at right angles to the claw, e.g., *Dianthus*.

**Papilionaceous** : Five free unequal petals arranged in definite fashion. The posterior petal is the largest and is called standard or vexillum. On either side of the standard, two lateral petals called wings are present. The remaining two anterior petals unite to form a boat shaped structure called the keel. e.g., plants of family papilionaceae.

(ii) **Gamopetalous corolla** : They are of following types :

**Tubular** : Five united petals form a cylindrical tubular structure, e.g., disc florets of Asteraceae.

**Infundibuliform** : It is a funnel shaped corolla, e.g., *Datura*.

**Campanulate** : It is bell shaped corolla, e.g., *Thevetia*.

**Rotate** : Short tubular corolla with spread out lobes appearing like a wheel e.g., Brinjal.

**Hypocrateriform** : It is a salver shaped corolla. It is provided with a elongated narrow tube having lobes at the top placed at right angles, e.g., *Vinca*.

**Ligulate** : Corolla with a short tube which is drawn out into a tongue shaped structure e.g., ray florets of Asteraceae.

**Bilabiate** : The irregular corolla is united, in such a way that it appears two lipped. It is the characteristic corolla of labiatae, e.g., *Leucas*.

(6) **Aestivation** : The arrangement of sepals and petals in bud condition of the flower is called "aestivation". It may be of following types :

**Open** : If the margins of perianth members in a whorl are free with wide gap between them, then the type of aestivation is called 'open', e.g., sepals of Mustard.

**Valvate** : Here the edges of perianth members in a whorl are very nearly touching each other but do not overlap, e.g., calyx and corolla in *Annona*

**Twisted** : In this type, the perianth members of a whorl show one edge outside and one edge inside. Thus they regularly overlap the neighbouring members on one side. The twisted aestivation is also called contorted or convolute aestivation, e.g., corolla of *Hibiscus*.

**Imbricate** : Here in a whorl of perianth members, one is completely inside and another is completely outside. The remaining perianth members show one edge inside and the other edge outside. The imbricate aestivation is of two types, namely, descending imbricate and ascending imbricate.

**Descending imbricate** : Here the odd petal is posterior and completely outside. The anterior pair of petals are completely inside. The remaining petals show regular overlapping in the descending manner. e.g., *Tephrosia*, *Crotalaria* and *Dolichos*.

**Ascending Imbricate** : Characteristic of corolla of family Caesalpiniaceae. Here the odd petal is posterior and completely inside. One of the anterior petals is completely outside. The remaining petals show regular overlapping in ascending manner, e.g., *Cassia* and *Delonix*.

**Quincuncial** : In this type, out of the five perianth members in a whorl two are completely outside, two are completely inside and the remaining has one edge outside and one-edge inside. This is confined to pentamerous flowers only, e.g., sepals of *Ipomoea*, *Vinca* and *Thevetia*.

**Vexillary** : Same as papilionaceous corolla.

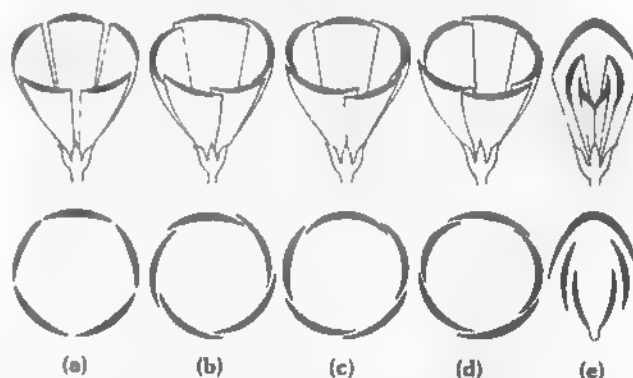


Fig : 2.1-11 Different types of aestivation  
(a) Valvate, (b) Twisted, (c) Imbricate,  
(d) Quincuncial (e) Vexillary

(7) **Androeclium or Stamens** : It is the third whorl of a flower consisting of stamens or microsporophylls. Fertile stamens produce pollen grains. Staminodes are the sterile stamens. Petaloid stamens are brightly coloured and appear like petals, e.g., *Canna*.

(i) **Structure of stamen** : A stamen shows a long or short stalk called the filament. The filament ends with a terminal fertile part known as the anther. It encloses microsporangia within which microspores or pollen grains are produced. The filament of the stamen is connected to the anther by means of a "connective". The anther may be monothealous or dithealous. The monothealous anther has only one sac. It is bilocular or bisporangiate, e.g., *Hibiscus*. The dithealous anther consists of two sacs and is tetralocular or tetrasporangiate as in *Datura*.

When the face of anther is towards centre of flower it is called introrse e.g., tomato when it is towards the periphery it is called extrorse /e.g., *Ranunculus*.

(ii) **Fixation** : The mode of attachment of a filament to anther by connective is called fixation. It is of following types :

**Adnate** : Filament attached to the total length of the anther on the back. e.g., *Michelia* (Champa).

**Basifixed** : Filament is attached to the base of the anther e.g., *Datura*, Mustard, Radish.

**Dorsifixed** : Filament is attached to the anther on the dorsal side at middle portion e.g., *Passiflora*.

**Versatile** : Filament is attached to the anther at a point so that anther can swing freely in all direction. e.g., Grasses.

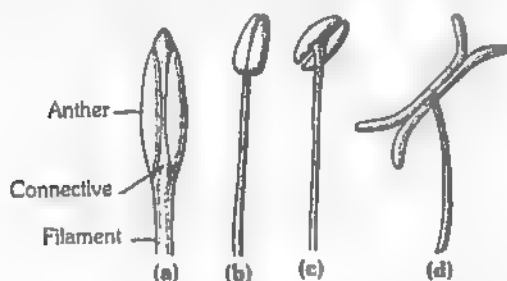


Fig : 2.1-12 Attachment of anther to filament  
(a) Adnate, (b) Basifixed, (c) Dorsifixed, (d) Versatile

(iii) **Length of stamens** : Based on the relative lengths of the stamens, the conditions of androecium varies

**Didynamous** : When there are four stamens in a flower of which two are long and two are short, the condition is described as didynamous, e.g., *Ocimum*.

**Tetradynamous** : Out of the six stamens that are found in a flower, four stamens are long and the two are short. This condition is called tetradynamous, e.g., *Raphanus* and *Brassica*.

The stamens are described as inserted when they do not extend beyond the petals or corolla tube (*Dolichos*). When the stamens extend beyond the petals or corolla tube, the stamens are known as exserted (*Acacia*).

(iv) **Insertion of stamens** : Based on the insertion of stamens, the condition of androecium varies :

**Isostemonous** : When the stamens form a single whorl and the number of stamen is the same as that of sepals and petals, the flower is isostemonous. (e.g., *Solanum*) while heterostemonous condition is used for any difference in size, shape or mode of dehiscence.

**Diplostemonous** : Sometimes there are two whorls of stamens. The first whorl alternating with petals (antisepalous) and the second whorl alternating with sepals (antipetalous). e.g., *Cassia*.

**Obdiplostemonous** : In this condition first whorl is antipetalous and the second whorl is antisepalous. e.g., *Dianthus*.

(v) **Union of stamens** : The union of stamens takes place either among themselves (*cohesion*) or with other whorls (*adhesion*).

**Cohesion of stamen** : Usually following types of cohesion among stamens occur. They are :

**Adelphous** : When the filaments of stamens are united and the anthers remain free. It is of three types :

**Monodelphous** : All filaments unite to form a single bundle e.g., Family malvaceae (*Hibiscus*).

**Diadelphous** : Filaments unite to form two bundles. e.g., Family papilionaceae (*Pisum*, *Sesbania*, *Tephrosia*). i.e.,  $(q) + 1$ .

**Polyadelphous** : Filaments unite to form many bundles. e.g., Family rutaceae (*Citrus*, *Melaleuca*).

**Syngenesious** : When the anther of filament are united and the filaments remain free. e.g., *Tridax*, Sunflower etc.

**Synandrous** : Here all stamens of a flower are united completely to form a single structure. e.g., Family Cucurbitaceae.

**Adhesion of stamens** : Stamens may unite with other floral organs like sepals, petals or gynoecium. Based on the floral organ involved in the union with stamens, the adhesion may be of the following types :

**Epiphyllous** : Stamens unite with perianth. e.g., Onion.

**Episepalous** : Stamens unite with sepals. e.g., *Prunus* (Peach).

**Epipetalous** : Stamens unite with petals. e.g., *Datura*.

**Gynandrous** : Stamens unite with gynoecium. It is also called gynandrium or gynostegium. e.g., *Calotropis*.

(8) **Gynoecium or Carpels** : The gynoecium or pistil is the fourth essential whorl of female reproductive part of the flower and may be made up of one or more carpels (megasporophylls). A carpel has three distinct part, namely ovary, style and stigma.

The lower most swollen fertile part of the carpel is the ovary. It encloses ovules. A sterile pistil is known pistillode. The number of carpels in a gynoecium varies in different flowers.

**Monocarpellary** : It is a gynoecium with a single carpel, e.g., Bean.

**Bicarpellary** : It is presence of two carpels in a gynoecium. e.g., *Helianthus*.

**Tricarpellary** : It is presence of three carpels in a gynoecium e.g., *Cocos*.

**Tetracarpellary** : It is presence of four carpels in a gynoecium. e.g., Cotton.

**Pentacarpellary** : It is presence of five carpels in a gynoecium. e.g., *Hibiscus*.

**Multicarpellary** : It is presence of many carpels in a gynoecium. e.g., *Annona*.

The ovary encloses one to many chambers called the locules. Based on the number of locules, the ovary may be described as follows :

**Unilocular** : Ovary with one locule. e.g., *Dolichos*.

**Bilocular** : Ovary with two locules. e.g., *Solanum*.

**Trilocular** : Ovary with three locules. e.g., *Allium*.

**Tetralocular** : Ovary with four locules. e.g., *Datura*.

**Pentalocular** : Ovary with five locules. e.g., *Hibiscus*.

**Multilocular** : Ovary with many locules. e.g., *Abutilon*.

**Apocarpous** : Pistil or gynoecium with separate or free carpels e.g., in *Ranunculus*

**Syncarpous** : Condition of fused carpels.

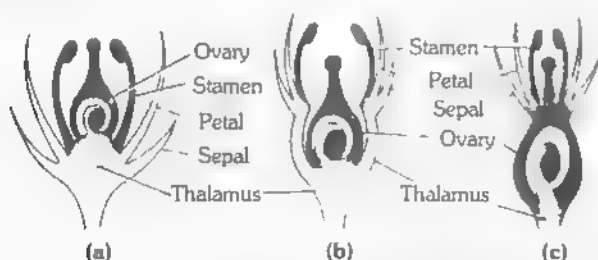
**(8) Relative position of floral organs on thalamus :**

Depending upon the form of thalamus and the position of floral whorls with respect to the ovary, the flowers are of the following three types :

(i) **Hypogyny** : In this case the thalamus is convex and ovary occupies the highest position on it. The outer three whorls, viz. sepals, petals and stamens inserted one above the other but below the ovary. Since the ovary lies above the other parts, it is described as superior and the rest of the floral whorls as inferior. A flower having hypogyny is called hypogynous. e.g., China rose, Brinjal, Mustard, etc.

(ii) **Perigyny** : In some cases, the receptacle or the thalamus forms a swallow or deep cup-shaped structure around the ovary. The pistil is attached at the centre of the concave thalamus. The sepals, petals and stamens are attached at the margins of the thalamus, the flowers are said to be perigynous and ovary is half inferior or half superior. Different type of flowers show different degrees of perigyny. e.g., Rose, Pea, Bean, Prunus, etc.

(iii) **Epigyny** : In this condition the margin of thalamus grows further upward completely enclosing the ovary and getting fused with it and bear the sepals, petals and stamens above the ovary. The ovary in such cases is said to be inferior and the rest of the floral members superior. e.g., Apple, Sunflower, Cucumber, Guava, etc.



**Fig : 2.1-13 Insertion of floral parts on thalamus**  
(a) Hypogynous, (b) Perigynous, (c) Epigynous

**(9) Placentation** : The ovary contains one or more ovules, which later become seeds. The ovule bearing regions of the carpel is called *placenta*. The arrangement of placentae and ovules within the ovary is called *placentation*. The placenta is the cushion-like structure to which the ovules are attached inside the cavity of the placenta, placentation is of the following types :

(i) **Marginal** : In this type of placentation, the ovary is simple, unilocular and the ovules are arranged along the margin of the unilocular ovary. The placenta develops along the ventral suture of the ovary. e.g., Pea, Gram, Goldmohur, etc.

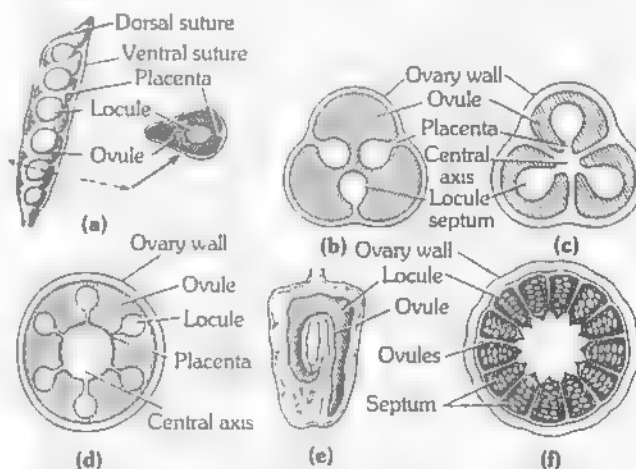
(ii) **Axile** : It is found in a compound ovary which is two or more chambered, usually as many as the number of carpels e.g., *Petunia* and *Asphodelus*. The placentae bearing the ovules develop from the central column or axis which is formed by the fusion of margins of carpels. In certain cases the number of chambers (loculi) increases due to the false septum formation. e.g., *Datura*, *Tomato*, etc.

(iii) **Free central** : In this free central placentation, the gynoecium is polycarpellary and syncarpous. The ovary in early stages is multilocular, but soon the septa break down leaving it as a unilocular structure. e.g., *Dianthus*, *Silene*, *Primula*, etc.

(iv) **Parietal** : In parietal placentation, the ovary is usually one-chambered but in some cases it becomes bilocular due to the formation of false septum called replum, e.g., *Brassica campestris* (Sarson). The placentae bearing the ovules develop on the inner wall of the ovary at places where the margins of two adjoining carpels meet. The number of placentae corresponds to the number of fused carpels e.g., *Poppy*, *Mustard*, *Cactus*, etc.

(v) **Basal** : In this type of placentation, ovary is bicarpellary, syncarpous and unilocular and a single ovule is borne at the base of ovary e.g., *Marigold*, *Sunflower*, etc.

(vi) **Superficial** : The ovary is multicarpellary, syncarpous, and large number of loculi without specific order e.g., *Waterlily* (*Nymphaea*).



**Fig : 2.1-14 Different types of placentations** (a) Marginal, (b) Parietal, (c) Axile, (d) Central, (e) Basal, (f) Superficial

**(10) Style** : The stalk like structure present above the ovary is called the style. The style may be long (*Datura*) or short (grasses) or absent (*Papaver*). In the family umbelliferae (apiaceae) the base of the style is swollen and forms a structure called *stylopodium*. There are three types of styles as described below :

(i) **Terminal style** : If the style arises from terminal part of the ovary, it is called terminal style, e.g., *Datura*, *Hibiscus* and *Solanum*

(ii) **Lateral style** : If the style arises from one side of the ovary, it is called lateral style, e.g., *Mango*.

(iii) **Gynobasic style** : If the style arises from the base of the ovary it is called gynobasic style. It is characteristic feature of family Labiatae., e.g., *Oedum*, *Salvia*.

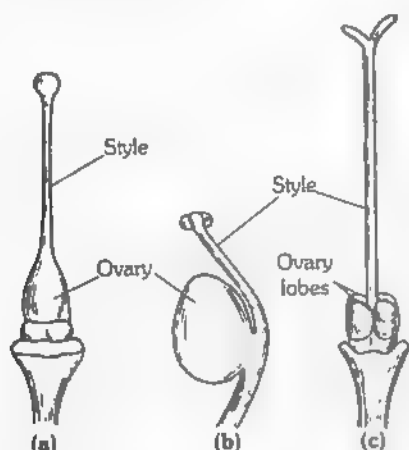


Fig : 2.1-15 Types of styles (a) Terminal, (b) Lateral, (c) Gynobasic style

(11) **Stigma** : The terminal receptive portion of the style is called the stigma. It receives pollen grains during pollination. Usually the lobes of the stigma corresponds to the number of carpels. Accordingly the stigma may be unifiid, bifid, trifid, tetrafiid, pentaifiid or multififiid.

**Capitate** : Round stigma. e.g., *Hibiscus*.

**Forked** : Divided stigma. e.g., *Tridax*.

**Feathery** : Brush like stigma. e.g., *Grasses*.

(12) **Floral formula** : It represents the informations given in a floral diagram in the form of an equation. Following symbols are used in constructing a floral formula.

Br.	Bracteate	C	Corolla-free (polypetalous)
Bri.	Bracteolate	(C)	Corolla-united (gamopetalous)
Ebr.	Ebracteate	Cx	Corolla-cruciform
Ebri.	Ebracteolate	P	Perianth
♂	Male	A	Androecium free (polyandrous)
♀	Female	(A)	Androecium-united (syndrous)
♂♀	Bisexual	P $\overleftarrow{\quad}$ A	Epiphyllous
⊕	Actinomorphic	C $\overleftarrow{\quad}$ A	Epipetalous
† or %	Zygomorphic	G	Gynoecium free (apocarpous)
Ep	Epicalyx	(G)	Gynoecium-united (syncarpous)
K	Calyx-free (polysepalous)	<u>G</u>	Superior ovary
(K)	Calyx-united (gamosepalous)	<u>G</u>	Inferior ovary
N	Neuter	G $\overleftarrow{\quad}$ A	Gynostegium

(12) **Floral diagram** : Following signs are used in constructing a floral diagram.

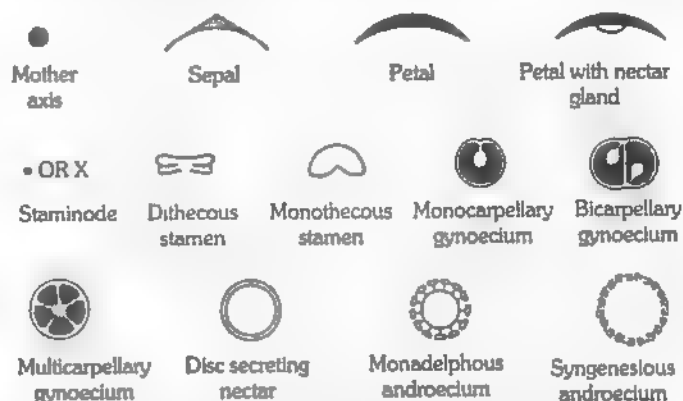


Fig : 2.1-16 Signs used in preparation of floral diagram

## Fruit

**Formation of fruit** : Fruit is defined as fertilized ovary. The ovary develops into fruit. The ovary wall at maturity forms the wall of the fruit, which is known as *pericarp*. Sometimes, other parts of flower such as *tepals*, (e.g., *Morus*), *bracts* (e.g., *Ananas*) or *thalamus* (e.g., *Pyrus*) are also involved in the formation of fruit and such fruits are called false fruits or pseudocarps.

The fate of various parts of the ovary during the formation of fruits is summarized below :

Ovary	—	Fruits
Ovary wall	—	Pericarp
Ovule	—	Seed
Funiculus	—	Stalk of the seed
Hilum	—	Hilum
Nucellus	—	Perisperm (when present)
Micropyle	—	Micropyle
Outer integument	—	Testa
Inner integument	—	Tegmen
<b>Embryo sac</b>		} Seed coat
Synergids	—	
Antipodals	—	} Degenerate
Egg cell	—	
Secondary nucleus	—	Embryo
	—	Endosperm

## Types of fruits

They are classified into three groups : Simple, aggregate and multiple or compound fruit.

**Simple fruits** : They are formed from mono-or polycarpellary but syncarpous ovary. They may be dry or fleshy.

(1) **Simple dry fruits** have thin, hard and dry, pericarp. They are of three kinds :

- Dehiscent or Capsular
- Achenial or Indehiscent
- Schizocarpic

(i) **Dehiscent fruit** : These fruits are dry, many seeded and split open at maturity. They are of following types :

**Legume or Pod** : It is characteristic of the family leguminosae; developed from monocarpellary unilocular superior ovary with marginal placentation. It can open or dehisces by both ventral and dorsal sutures. e.g., in *Cicer arietinum* (Gram); *Pisum sativum* (Pea) and *Phaseolus mungo* (Black gram).

**Follicle** : It is very much resembles the legume but on ripening it opens generally along the ventral suture. e.g., *Calotropis*, *Larkspur*, etc.

**Silique** : The fruit is developed from bicarpellary, syncarpous and superior ovary which bears ovules on two parietal placenta. The ovary is unilocular but later becomes bilocular due to the development of a false partition wall called *replum*. It dehisces from the base towards the apex by both the sutures e.g., in *Brassica* (Mustard) and is characteristic of the family *Cruciferae*.

**Silicula** : It is flattened and short in length from silique type, found in *Iberis* (Candytuft) and *Capsella bursa* (Shepherd's purse).

**Capsule** : It is mono or polycarpellary, dry dehiscent, many seeded fruit which develops from a superior or inferior ovary. It dehisces in almost all the ways i.e., longitudinal and transverse, along both the sutures. Majority of capsules show longitudinal dehiscence which again are of different types :

**Loculicidal** : Lines of dehiscence appear along the dorsal sutures, e.g., *Gossypium herbaceum* (Cotton) and *Abelmoschus esculentus* (Lady's finger).

**Septicidal** : Lines of dehiscence appear along the ventral sutures or septations of the ovaries e.g., in *Viola* (Pansy), *Linseed* (*Linum*).

**Septifragal** : Lines of dehiscence along irregular lines, but the seeds remain attached to the placenta, as in *Datura stramonium* (Thorn apple).

(ii) **Achenial or indehiscent fruits** : These fruits do not burst at maturity but the seeds are liberated only by the decaying of the pericarp. These are of following types :

**Achene** : It is small, dry one seeded fruit which develops from a superior or inferior monocarpellary ovary. In this type, the pericarp is tough but thin and free from the seed coat, e.g., in *Mirabilis* (four o'clock plant) and *Clematis*. Some times achenes occur in a group from apocarpous ovary where carpels are many e.g., *Nelumbium* (Lotus).

**Caryopsis** : It is very small, dry and one seeded fruit which develops from a superior monocarpellary ovary. Here the pericarp is closely fused with seed coat. It is the characteristic of family *graminae*, e.g., *Oryza sativa* (Paddy), *Triticum aestivum* (Wheat) and *Zea mays* (Maize).

**Cypsela** : It is dry, one seeded fruit which develops from an inferior, bicarpellary ovary. Here the pericarp is free from seed coat but the thalamus is fused with pericarp. The fruit is provided with a crown of hairs at the top called *pappus* e.g., in *Helianthus annuus* (Sun flower), *Tridax*, *Cosmos*, *Sonchus*, etc.

**Nut or Glans** : It is dry, one seeded fruit which develops from a superior, bi or polycarpellary ovary having a hard pericarp, free from seed coat e.g., in *Areca catechu* (Betelnut), *Anacardium occidentale* (Cashewnut) and *Trapa natans* (Water chestnut). Here the thalamus and sometimes the cotyledons of true fruit are also edible.

**Samara** : It is dry, one or two seeded fruit, develops from a single mono-or bicarpellary ovary. The pericarp is free from testa and produces a wing like outgrowth which helps in the dispersal of seeds e.g., in *Hiptage* and *Elm*.

(iii) **Schizocarpic or Splitting fruits** : These resemble both (achenial) indehiscent fruits as well as capsular fruits having many seeds. However, they break into one seeded segments known as *mericarps*. By splitting usually the *mericarps* are indehiscent but in *Ricinus* (Castor) they are dehiscent. The important schizocarpic fruits are :

**Lomentum** : It is a dry, many seeded fruits which develops from a monocarpellary, superior, unilocular ovary with marginal placentation.

The fruit arises just like a legume but when ripened it becomes partitioned between seeds into single seeded *mericarps* e.g., *Acacia arabica* (gum tree), *Mimosa* (touch me not) and *Dalbergia sisoo* (Indian red wood tree).

**Cremocarp** : It is a dry fruit, develops from bicarpellary, syncarpous, bilocular ovary. The fruit when mature breaks into single seeded *mericarps* which remain attached to the top of the central axis called *carpophore*, e.g., *Daucus carota* (Carrot); *Foeniculum vulgare* (fennel).

**Regma** : It develops from tri-or penta-carpellary superior syncarpous ovary. The locules are many as the carpels known as *Cocci* (sing. *Coccus*), attached to *carpophore* and separate by splitting e.g., *Euphorbia*, *Geranium* and *Ricinus*.

**Carcerulus** : It is a dry fruit, develops from bi or polycarpellary syncarpous, multilocular superior ovary with axile placentation. Many single seeded, *mericarps* are formed by splitting and formation of false septa. e.g., *Ocimum sanctum* (Sacred basil), *Althaea rosea*

(2) **Simple fleshy fruit** : The fruits are simple, but the pericarp is fleshy and edible. It is differentiated into three layers epicarp, mesocarp and endocarp. Fleshy fruits are of following types:

**Drupe** : It is a fleshy fruit formed from monoor polycarpellary superior ovary, where one or more ovules may develop into seeds. Here the epicarp is thin and leathery. The mesocarp is thick, fleshy, juicy and edible in *Mangifera* (Mango) and fibrous in *Cocos* (Coconut).

The endocarp is hard and stony in both the cases. In *Cocos*, pericarp is not edible. The portion inner to endocarp is the liquid endosperm which is edible.

**Berry** : It is usually many seeded fleshy fruit develops from polycarpellary, syncarpous, superior ovary. Rarely it is single seeded as in *Borassus* (Palm).



Here the epicarp remains as the skin of the fruit. The mesocarp and endocarp are fused together to form the pulp of the fruit, e.g., Brinjal, Tomato, Banana, etc.

**Pepo** : It is a special type of berry. Here the epicarp and thalamus form the outer ring of the fruit. The mesocarp, endocarp and placentae are fused to form pulp which is edible; seeds are many. It is characteristics fruit of family cucurbitaceae. Common examples are *Cucurbita maxima* (Sweet gourd); *Cucumis sativa* (Cucumber).

**Pome** : The fruit develops from inferior, pentacarpel ovary. The fruit is covered by the fleshy thalamus, which is fused with the pericarp and edible. The outer part again encloses the inner stiff and membranous portion enclosing the seeds; common example is *Pyrus indica* (Apple).

**Table : 2.1-1 : Edible Parts of Some Fruits**

Wheat	Endosperm and embryo
Maize	Endosperm and embryo
Litchi	Fleshy aril
Orange	Unicellular juicy hairs from endocarp
Lemon	Unicellular juicy hairs from endocarp
Apple	Fleshy thalamus
Pear	Fleshy thalamus
Strawberry	Fleshy thalamus
Banana	Mesocarp and endocarp
Cucumber	Mesocarp and endocarp
Muskmelon	Mesocarp and endocarp
Walnut	Cotyledons
Groundnut	Cotyledons and embryo lobe
Cashewnut	Cotyledons and fleshy pedicel
Pea	Cotyledons and embryo
Pomegranate	Juicy testa
Indian plum	Epicarp and mesocarp
Guava	Pericarp and placenta
Grape	Pericarp and placenta
Jack fruit	Bracts, perianth and seeds
Pineapple	External rachis, bracts, perianth and seed
Mulberry	Perianth
Fig	Rachis or fleshy receptacle
Coconut	Endosperm
Lotus	Thalamus and seeds
Custard apple	Mesocarp

**Hesperidium** : It is another type of berry; it develops from a polycarpellary, syncarpous, superior ovary with many seeds. Here the outer skin is thick and leathery that represents the epicarp, which contains oil glands. The fibrous portion fused with epicarp is the mesocarp. The endocarp consists of many chambers with juicy glands. Common examples are *Citrus medica* (Lemon) and *Citrus sinensis* (Sweet orange).

**Balausta** : This is many chambered, many seeded fruit developing from a multicarpellary, syncarpous but inferior ovary. The pericarp of balausta is leathery or tough. The carpels are arranged in two rows. Calyx is persistent. The seeds have succulent seed coat (testa) which form the edible part; e.g., *Punica granatum* (Pomegranate).

**Aggregate fruits** : The aggregate fruits are formed from polycarpellary, apocarpous ovary. Each ripened is called *fruitlet* or *etaerio* e.g., the lotus, rose fruit and strawberry are a collection of achenes; raspberry, a collection of drupes and custard apple is a collection of berries.

**Composite or compound fruits** : Multiple fruit develops from entire inflorescence called sorosis or syconus.

**Sorosis** : Develops from spike or spadix inflorescence e.g., Pineapple, Jackfruit, Mulberry, etc.

**Syconus** : Develops from hypanthodium inflorescence e.g., *Ficus carica*. (banyan).

## Seed

Morphologically, ripened ovule is known as seed. In other words, seed is mature integumented megasporangium.

**Development of seed** : The fertilized ovule forms seed. The ovule increases greatly in size. The integuments dry up. The outer one becomes hard or leathery and forms the outer seed coat or testa while the inner one, if persist, forms the tegmen.

The nucellus is generally used up during the development of embryo but in some cases it remains outside the endosperm in the form of a thin layer, called *perisperm*. The endosperm may persist or completely digested during embryogenesis.

A scar is usually visible on one side of the outer seed coat. It is known as *hilum* and marks the point of attachment to the stalk. With these changes, the ovule changes into seed and enters a period of dormancy while the ovary ripens into a fruit.

### Dicotyledonous seeds

**Exalbuminous** : Gram, Pea, Bean, Mustard, Mango, Groundnut, etc.

**Albuminous** : Castor, Poppy, *Artabotrys*, Custard apple (Ananas) etc.

### Monocotyledonous seeds

**Exalbuminous** : Orchids, *Alisma*, *Najas*, *Pothos*, *Amorphophallus*, *Vallisneria*, etc.

**Albuminous** : Cereals, Millets, Palms, Lilies, etc.



**Non-endospermic or Exalbuminous seeds :** In exalbuminous seeds endosperm is completely consumed by the developing embryo, and the mature seeds are without endosperm. The food is stored in cotyledons.

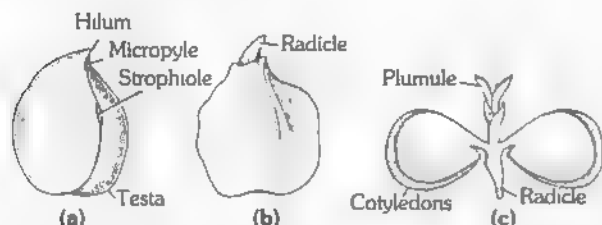


Fig : 2.1-17 Structure of gram seed

**Endospermic or Albuminous seed :** In albuminous seeds, embryo not consumed all endosperm. So it persists in the mature seed. In these seeds food stored in endosperm. In monocot seed the membranous covering of :

- ☐ Radicle is called coleorrhiza.
- ☐ Plumule is called coleoptile.

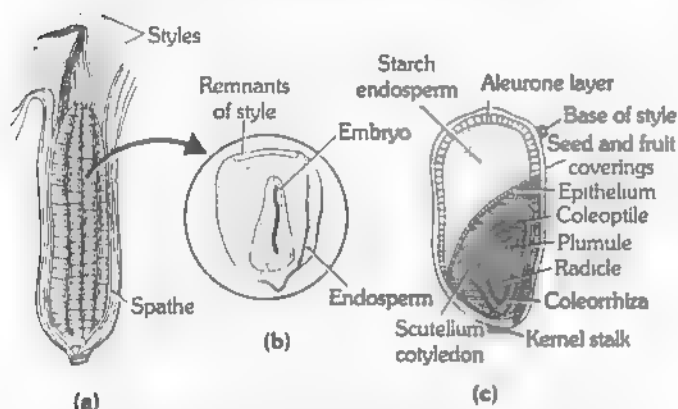


Fig : 2.1-18 Structure of maize grain  
(a) Entire seed; (b) Grain in L.S. (c) Grain in T.S.

**Germination of seeds :** The process by which the dormant embryo of the seed resumes active growth and grows into a new plant is known as germination.

#### Types of seed germination

**Epigeal germination :** In this type of germination, the cotyledons come above the surface of the soil into the air and light due to the rapid growth and elongation of the hypocotyl. The cotyledons turn green and finally dry up and fall off and seedling becomes an independent plant. Germination of seeds of Bean, Gourd, Castor, Cotton, etc. is of epigeal nature.

**Hypogeal germination :** In this type of germination, the cotyledons remain in the soil or just above the surface. In this case epicotyl elongates pushing the plumule upwards. The cotyledons do not turn green and gradually dry up and fall off. Common examples of hypogeal germination are the seeds of Pea, Mango, Groundnut, etc.

**Viviparous germination :** This is a special type of germination found in mangrove plants. The embryo grows not only out of the seed but also out of the fruit and projects from it in the form of a green seedling displaying root and hypocotyl. Due to its increasing weight the seedlings separate from the parent tree and falls into the mud or water and soon develops lateral roots. Vivipary is seen in *Rhizophora* and *Sonneratia*.

#### Factors for seed germination

**External factors :** Water, oxygen, suitable temperature.

**Internal factors :** Foods and growth regulators, completion of rest period, viability.

**Seed dormancy :** In several plants seeds germinate as soon as they have undergone maturation and provided proper conditions for germination. e.g., seeds of Bean, Pea, Maize etc. In some plants seeds are incapable of germination because of some inhibitory factors. Such seeds are unable to germinate even under suitable conditions. This is called seed dormancy.

**Viability of seeds :** Germinating ability of the seed is called its viability. Only viable seeds are able to germinate. As the viability expires, the embryo dies and seed loses its capacity of germination. Viability of seeds varies from species to species.

☐ Longest seed viability is reported in *Nelumbo nucifera* (= *Nelumbium speciosum*) or **Indian lotus** (Kamal). Here the viability is reported to be **more than two hundred years**.

#### Causes of seed dormancy

The seed dormancy may be due to many causes some of which are as follows :

- (1) Impermeability of seed coats to oxygen. (e.g., *Xanthium*) and water. (e.g., *Chenopodium* and many leguminous seeds).
- (2) Seed coat is mechanically hard, thus resisting the growth of embryo. e.g., Mustard, *Capsella*, *Amaranthus*.
- (3) Presence of rudimentary or immature embryo. e.g., *Ginkgo biloba* (a gymnosperm).
- (4) Some plants produce such chemical compounds that inhibit the germination of their own seeds. e.g., *Tomato*, (possesses inhibitor ferulic acid).

#### Dispersal of fruits and seeds

##### Dispersal by wind (Anemochory)

The wind is probably the most important agency of seed dispersal in nature. The fruits and seeds show following devices which help in dispersal by wind

**Light weight and minute seeds :** Seeds of some plants (e.g., *Orchids*) are sufficiently light and minute in size to be easily carried away to great distances by air currents.

**Winged seeds and fruits :** Some seeds (e.g., *Oxylon*, *Cinchona*, *Moringa*) or fruits (*Acer*, *Hiptage*, *Terminalia*, *Dipterocarpus*) develop one or more thin membranous wings to ensure their dispersal by wind.

**Parachute mechanism :** In members of the family Asteraceae (Compositae) e.g., *Taraxacum*, *Sonchus*, sepals are modified into tufts of hairs called *pappus*. The pappus is persistent and hence found attached to even small, single seeded fruits. It acts like a parachute that allows the wind to carry them to great distances. Seeds of many nasty weeds are also dispersed by this method.

**Coma :** One or more tufts of hairs are attached on seeds constitute coma, e.g., *Calotropis*, Cotton etc.

**Censer mechanism :** In *Antirrhinum* (dog flower), *Aristolochia*, *Papaver* (poppy), *Argemone mexicana* (Prickly poppy), *Nigella* (love-in-a-mist), etc. the fruit is a capsule. At maturity it ruptures but the seeds do not come out. However, when the capsule is shaken violently by the wind, the seeds are scattered in all directions. In this process all the seeds do not escape together.

**Rolling mechanism :** In some species, like *Amaranthus albus*, *Chenopodium album*, etc., plants dry out after bearing fruits and seeds. Eventually the entire plant breaks off at the base of the stem due to the force of wind and rolls over the ground, shedding the seeds all along the way. Such rolling plants are collectively known as tumble weeds.

**Hairs :** In cotton, hairs are the outgrowth from the seed coat and occur all along its surface.

**Persistent styles :** *Clematis*, *Naravella*, *Geranium* etc. have persistent and feathery styles which help the fruit to be easily carried by wind.

**Balloon like appendages :** In plants like *Cardiospermum* and *Nicandra* fruits develop balloon like appendages which make the fruits light to be easily carried by wind.

#### **Dispersal by water (Hydrochory)**

Fruits and seeds, specialized for dispersal by water, generally develop some kind of floating devices and a protective covering which makes them water resistant. e.g., fibrous mesocarp in Coconut, spongy thalamus in Lotus. The seeds of *Polygonum* can be held over the surface of water and dispersed.

#### **Dispersal by animals (Zoochory)**

Fruit and seeds dispersed by animals can be divided into following three categories on the basis of their adaptive features

**Hooked fruits and seeds :** The surface of many fruits is covered with hooks (e.g., *Xanthium*, *Urena*), barbs (e.g., *Andropogon*), spines (e.g., *Tribulus*), bristles (e.g., *Pupalia*), or stiff hairs (e.g., *Aristida*), by means of which they adhere to the body of animals or clothes of human beings and they are carried unwarily from one place to another.

**Sticky fruits and seeds :** Some fruits like those of *Boerhaavia*, *Cleome*, and *Plumbago* have sticky glands by which they adhere to the fur of grazing animals and are thus dispersed. Seeds of *Viscum* (mistletoe), *Loranthus*, etc. have a viscid layer which adhere to the beak of the bird which eat them. Sticky seeds of *Rafflesia* are dispersed by elephants.

**Edible fruits :** (i) The seeds are very small and capable of passing unharmed through digestive tract of animals (e.g., Mulberry, Peepal, Guava, Banyan, Tomato). (ii) The seeds are large so that they are thrown away, e.g., Apricot, Mango. (iii) Sticky so that stick to the beaks of birds. The seeds are thrown away by rubbing of beaks, e.g., *Viscum*, *Cordia*, *Loranthus*.

#### **Dispersal by explosive or Spring like mechanism (Autochory)**

A less common method of seed dispersal is by means of explosive fruits. Such fruits open with force and scatter the seeds in all directions. e.g., Balsam fruit (*Impatiens*), *Oxalis*, night jasmine (*Nyctanthus*), castor (*Ricinus*), camel's foot climber (*Bauhinia vahlii*), Pea etc. Another example of autochory is the seeds of *Ecballium* (squirting cucumber). In squirting cucumber the fleshy and spiny fruit wall encloses a mucilaginous mass having seeds. The tip of the stalk functions as a plug. Disturbance breaks the fruit from the stalk. The mucilage containing the seeds is thrown out with a great force.

### **Taxonomy of Angiospermic plants**

#### **Liliaceae**

##### **Systematic position**

Division	:	Angiospermae
Class	:	Monocotyledonae
Series	:	Coronarieae
Order	:	Liliales
Family	:	Liliaceae

**Habit :** Usually perennial herbs growing by means of rhizomes (e.g., *Aloe*, *Polygonatum*), bulbs (e.g., *Lilium*, *Allium*) and corms (e.g., *Colchicum*). Some herbs are annual (e.g., *Asphodelus*). Shrubs occur in *Aloe*, *Agave*, *Yucca* (Dagger plants, Adam's Needle), *Dracaena* (Dragon plant), and *Ruscus* (Butcher's Broom). They mostly grow in arid areas and are hence xerophytic (e.g., *Aloe*, *Yucca*). *Xanthorrhoea* of Australia is tree-like. Climbers are seen in *Smilax*, *Gloriosa* and species of *Asparagus*.

**Root :** Adventitious, fibrous or tuberous (e.g., *Asparagus*).

**Stem :** Erect or climbing as *Smilax*, branched or unbranched, herbaceous, phylloclade as *Ruscus*. Cladode as *Asparagus*, Bulb as *Allium cepa*.

**Leaves :** Radical or cauline and ramal show various types of phyllotaxy (alternate, opposite or whorled), exstipulate, stipulate in *Smilax* where the stipules are prolonged into tendrils, sessile or petiolate with sheathing leaf bases, venation parallel but reticulate in *Smilax*, leaves may be scaly, leathery, fleshy or modified into spines (e.g., *Asparagus*), leaf apex is tendrillar in *Gloriosa*. The leaves of *Phormium tenax* (New Zealand Hemp) are 3 metres long and 10 cm broad.

**Inflorescence** : Recemose, sometimes solitary (e.g., *Tulipa*, *Gloriosa*) or umbellate condensed cymes (umbel cyme), e.g., Onion. In several cases the inflorescence possesses a leafless peduncle called scape.

**Flower** : Bracteate or ebracteate, pedicellate, regular, trimerous actinomorphic, zygomorphic in a few cases (e.g., *Gilliesia*), complete or incomplete, perfect, unisexual in *Smilax* and *Ruscus*, hypogynous, generally pentacyclic, trimerous (rarely bimerous or tetramerous). Accessory floral organs undifferentiated and collectively called perianth.

**Perianth** : Tepals 6 (coloured), in two whorls of 3 each, free or fused, sepaloid or petaloid, scarious or membranous, aestivation valvate or imbricate, distinguished into calyx and corolla in *Trillium*.

**Androecium** : Stamens 6 (3 in *Ruscus*, 9–12 in *Tofieldia*), free (polyandrous) or monadelphous (e.g., *Ruscus*), arranged in two whorls, antiphyllous (antitepalous), may be epiphyllous (or epitepalous), anthers fixed variously (basifixed, dorsifixed, versatile), dehiscence longitudinal or by pores

**Gynoecium** : Tricarpellary, syncarpous, ovary superior, trilocular with 2-many ovules in each locules, placentation axile, rarely parietal, styles united or separate, stigma free or fused, trilobed.

**Fruit** : A capsule (e.g., *Asphodelus*, *Gloriosa*) or berry (e.g., *Asparagus*)

**Seed** : Endospermic and monocotyledonous.

**Floral formula** :  $\oplus \frac{\sigma}{\sigma} P_{(3+3)} A_{3+3} G_{(3)}$

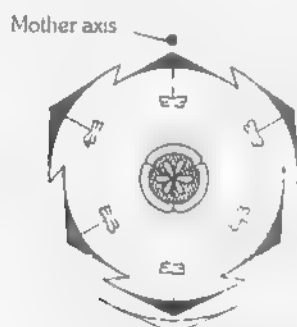


Fig : 2.1-19 Floral diagram of Iiliaceae (*Allium cepa*)

### Economic Importance of the family

#### (1) Sources of medicines

(i) *Colchicum luteum* and *C. autumnale* (Hirantutiya) : An alkaloid '**Colchicine**' is obtained from seeds and corms, which is used in the cure of rheumatism and liver disorders.

It is also drug of choice in acute gout.

Beside **Colchicine** is used for inducing polyploidy in plant breeds by arresting or breaking spindle formation.

(ii) *Aloe vera* (Aloe or Ghee Kavar) : Used in many laxative preparations and also used in curing piles and fissures.

(iii) *Urginea indica* and *U. maritima* (Indian squill) : Bulbs stimulate heart and are also used in rheumatism and skin diseases.

Raticide or Red-squill is prepared from bulbs of red variety, which is an important raticide (rat killer) for more than 20 years.

(iv) *Smilax macrophylla* and *S. glabra* (Sarasparilla) : Roots provide a drug called '**Sarasparilla**' which is cure of venereal and skin diseases.

(v) *Gloriosa superba* (Malabar glory lily) : Tubers are used in promotion of labour pains and juice of leaves is used for killing lice.

#### (2) Sources of food

(i) *Allium cepa* (Onion or Plaz)

(ii) *Allium sativum* (Garlic or Lahsun)

(iii) *Asparagus officinalis* and *A. racemosus* (Satawar)

#### (3) Source of fibres

(i) *Sansevieria roxburghiana* (Bowstring hemp) : Leaves provide a strong fibre, which is used for making bowstrings and fishing nets.

(ii) *Yucca filamentosa* (Dagger plant) : Leaves provide fibres used for cordage.

#### (4) Ornamentals

(i) *Tulipa* sps. (Tulip) : Beautiful flowers, etc.

(ii) *Lilium bulbiferum* (Lily) : For beautiful flowers.

(iii) *Yucca gloriosa* : White flowers giving perfume during night.

(iv) *Gloriosa superba*.

(v) *Asparagus plumosus* (Asparagus fern).

### Cruciferae or Brassicaceae (Mustard family)

#### Systematic position

Division	:	Angiospermae
Class	:	Dicotyledonae
Subclass	:	Polypetalae
Series	:	Thalamiflorae
Order	:	Parietales
Family	:	Cruciferae (Brassicaceae)

**Habit** : Annual, biennial or perennial herbs. *Farsetia jacquemontii* is an undershrub. The plants possess pungent juice having sulphur-containing glucosides.

**Root** : Tap root alongwith hypocotyl is swollen in Radish (*Raphanus sativus*) and Turnip (*Brassica rapa*).

**Stem** : Erect, cylindrical, hairy or glabrous, herbaceous or rarely woody. It is reduced in the vegetative phase in Radish and Turnip. The stem is swollen in Kohlrabi (Knol-Kohl = Ganthgobi, *Brassica oleracea* var. *gongylodes*). Axillary buds enlarged in Brussel's Sprouts (= Button gobi) or *Brassica oleracea* var. *gemmifera*. *Brassica oleracea* var. *capitata* (Cabbage) has the largest terminal bud

**Leaves** : Radical, cauline and ramal, alternate or sub-opposite but forming rosettes when radical, exstipulate with sheathing leaf base, sessile simple or rarely compound (e.g., *Nasturium officinale*), hairy. Bulbils occur in the leaf axils of *Dentaria bulbifera* and on the leaves of *Cardamine pratensis*.

**Inflorescence** : Flowers are usually arranged in corymbose racemes. Occasionally they are in corymbs (candituft).

**Flower** : Ebracteate or rarely bracteate (e.g., *Rorippa montana*), pedicellate, complete, perfect, regular, actinomorphic, rarely zygomorphic (e.g., *Iberis*, *Teesdalia*), tetramerous or bimerous, hypogynous (perigynous in *Lepidium*), cyclic, cruciform.

**Calyx** : Sepals 4, polysepalous, aestivation imbricate, generally arranged in two whorls, outer of antero-posterior sepals and inner of lateral sepals, lateral sepals generally saccate or pouched at the base, green or petaloid, inferior.

**Corolla** : Petals 4, polypetalous, arranged in one whorl and alternate with sepals, often with long claws and spread out in the form of a Greek cross. This arrangement of petals which is characteristic of the family is known as the cruciform arrangement and corolla is described as cruciform corolla, valvate aestivation. Petals reduced or absent in *Lepidium* and *Rorippa*.

**Androecium** : Stamens 6, (four in *Cardamine hirsuta*, two in *Coronopus didymus*, 16 in *Megacarpaea*), free (polyandrous), tetradynamous, arranged in two whorls, outer of two short lateral stamens while the inner whorl is made up of 4 long stamens arranged in two median pairs, anthers basifixed or dorsifixed, dehiscence longitudinal. Green nectaries are often associated with the bases of stamens.

**Gynoecium** : Bicarpellary (tricarpellary in species of *Lepidium*, tetracarpellary in *Tetrapoma* and *Tropidocarpum*), syncarpous, carpels placed transversely, ovary superior, placentation parietal, ovary bilocular due to the presence of a false septum called replum, style short, stigma capitate, simple or lobed.

**Fruit** : Siliqua or silicula, lomentaceous siliqua occurs in radish.

**Seed** : Non-endospermic, often oily.

**Floral formula** :  $\text{Ebr } \oplus \text{ } \overline{\text{K}}_{2+2} \text{ } \overline{\text{C}}_{\times 4} \text{ } \overline{\text{A}}_{2+4} \text{ } \overline{\text{G}}_{(2)}$

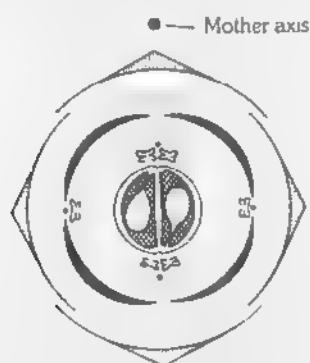


Fig : 2.1-20 Floral diagram of cruciferae (*Brassica campestris*)

#### Economic importance of family

##### (1) Medicines and spices

- (i) *Rorippa montana* : It is stimulant and also a good appetizer
- (ii) *Cherianthus cheiri* : Fever and bronchitis are cured by the seeds of this plant.

(iii) *Lepidium sativum* : Liver troubles, asthma and piles are cured by tender shoots.

(iv) *Iberis amara* : In gout and rheumatism.

(v) *Lobularia* : Used in gonorrhoea.

(vi) *B. alba*, *B. nigra* and *B. juncea* (rye) : Seeds are used as spices.

##### (2) Vegetables (Food)

(i) *Brassica rapa* (Turnip or Shalagm)

(ii) *B. oleracea* var. *caulorapa* (*gongylodes*) – (Knol - Khol or Ganth gobhi)

(iii) *B. oleracea* var. *capitata* (Cabbage or Band Gobhi)

(iv) *Brassica campestris* var. *sarson* (Pili Sarson)

(v) *B. oleracea* var. *botrytis* (Cauliflower or Phool Gobhi)

##### (3) Oils

(i) *Eruca sativa* (Taramira) : Taramira oil is obtained from seeds.

(ii) *Brassica juncea* (Indian mustard or Rye) : Seeds produce oil.

(iii) *Brassica napus* or *B. campestris* var. *torla* – Seeds are source of 'Indian rape oil' or Tel torla.

(iv) *Brassica campestris* : Seeds are source of Colza (Sarson Ka Tel).

##### (4) Ornamentals

(i) *Iberis amara* (Candytuff or Chandini) : Winter herb grown for its white, beautiful flowers.

(ii) *Cherianthus cheiri* (Wall flower).

### Leguminosae or Fabaceae

#### Systematic position

Division	: Angiospermae
Class	: Dicotyledonae
Subclass	: Polypetalae
Series	: Calyciflorae
Order	: Rosales
Family	: Leguminosae

**Habit** : Annual or biennial, herb, shrub or tree.

**Root** : Tap root system.

**Stem** : Erect or creeping, solid or weak.

**Leaf** : Alternate or whorled, stipulate, petiolate, simple or usually compound, reticulate venation. Leaves or leaflets modified into tendrils, two lateral leaflets of telegraph plant (*Desmodium motorium* or *D. gyrans*) show autonomous movements.

On the basis of inflorescence and flower characters, this family is divided into 3 subfamilies :

#### Subfamily - Papilionatae (Papilionaceae)

**Inflorescence** : Racemose or solitary axillary.

**Flower** : Bracteate or ebracteate rarely bracteolate (e.g., *Arachis*), pedicellate, complete, irregular, zygomorphic, perigynous occasionally, hypogynous, pentamerous.

**Calyx** : Sepals 5, gamosepalous, usually campanulate, lobes unequal, rarely tubular (e.g., *Cyamopsis*), odd sepal anterior, may be persistent, inferior

**Corolla** : Petals 5, polypetalous, papilionaceous, descending imbricate aestivation, one posterior long standard, two lateral short wings, two anterior petals jointed to each other forming keel.

**Androecium** : Stamens 10, usually diadelphous (9+1 in *Lathyrus*, 5+5 in *Aeschynomene*) or monadelphous (9 in *Dalbergia*, 10 in *Arachis* and *Erythrina indica*), rarely free (e.g., *Sophora*), nectar gland often present on the inner bases of filaments, anther lobes bilocular, dorsifixed, introrse.

**Gynoecium** : Monocarpellary, ovary superior, unilocular with marginal placentation ovary covered by staminal tube, style bent, stigma simple or capitate.

**Fruit** : Legume or lomentum.

**Floral formula** :  $\text{Br } \% \text{ } \underset{\text{5}}{\text{K}} \text{ } \text{C}_{1+2+(2)} \text{ } \text{A}_{1+(9)} \text{ } \underline{\text{G}_1}$

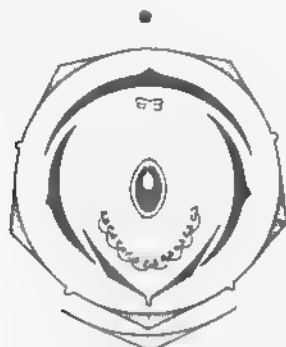


Fig : 2.1-21 Floral diagram of subfamily Papilionatae (*Pisum sativum*)

### Subfamily – Caesalpinoideae (Caesalpinaceae)

**Inflorescence** : Raceme, umbel or a solitary flower.

**Flower** : Bracteate or ebracteate, pedicellate, hermaphrodite, complete, zygomorphic, hypogynous.

**Calyx** : Sepals 5, polysepalous, imbricate aestivation.

**Corolla** : Petals 5, polypetalous, ascending imbricate aestivation.

**Androecium** : 10 stamens, or staminodes are found as in *Cassia*, free filaments of unequal size, anther lobes bilocular, introrse, versatile

**Gynoecium** : Monocarpellary, unilocular, ovary superior, marginal placentation, stigma capitate.

**Fruit** : Legume.

**Floral formula** :  $\% \text{ } \underset{\text{5}}{\text{K}} \text{ } \text{C}_5 \text{ } \text{A}_{1+2+2+3 \text{ (staminodes)}}$  OR

$7+3 \text{ (staminodes) } \underline{\text{G}_1}$

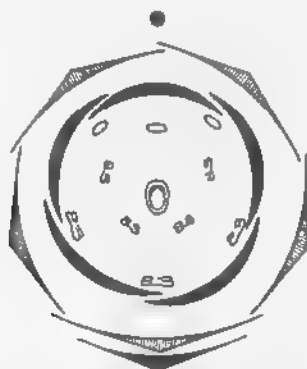


Fig : 2.1-22 Floral diagram of subfamily Caesalpinoideae (*Cassia fistula*)

### Subfamily – Mimosoideae (Mimosaceae)

**Inflorescence** : Head or capitulum or spike, flowers arranged in acropetal succession.

**Flower** : Bracteate or ebracteate, sessile, hermaphrodite, complete actinomorphic, hypogynous, pentamerous.

**Calyx** : 5 sepals (4 in *Mimosa*) gamosepalous, connate at the base, valvate aestivation, rarely imbricate (e.g., *Parkia*).

**Corolla** : 5 petals (4 in *Mimosa*) gamopetalous or polypetalous, membranous, valvate aestivation.

**Androecium** : In most of the members, stamens are indefinite and polyandrous. However, there are only 4 stamens in *Mimosa pudica* and 10 each in *Prosopis* and *Dichrostachys*. Filaments are long, usually connate at the base, sometimes they are coloured and gland dotted. Anthers are ditheous and introrse.

**Gynoecium** : Monocarpellary, unilocular, ovary superior, style long, cylindrical, stigma single and capitate, marginal placentation.

**Fruit** : Lomentum.

**Floral formula** :  $\text{Br or Ebr } \oplus \text{ } \underset{\text{4}}{\text{K}} \text{ } \text{C}_4 \text{ } \text{A}_4 \text{ } \underline{\text{G}_1}$

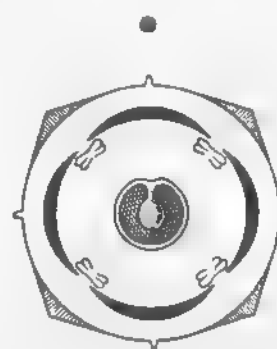


Fig : 2.1-23 Floral diagram of subfamily Mimosoideae (*Mimosa pudica*)

### Economic Importance of family

#### (1) Source of pulses (food)

Pulses we eat, are obtained from seeds of the members of this family, which are **rich source of proteins**.

- (i) *Pisum sativum* (Garden pea or pea).
- (ii) *Cicer arietinum* (Chick pea or Gram or Bengal gram).
- (iii) *Cajanus cajan* (Pigeon pea or Red gram or Arhar).
- (iv) *Vigna radiata* (Green gram or Moong).
- (v) *V. mungo* (Black gram or Urd)
- (vi) *V. sinensis* (Cow pea or Lobia)
- (vii) *Lens culinaris* Syn. *L. esculenta* (Lentil or Masoor).
- (viii) *Phaseolus vulgaris* (French bean) : Vegetable.
- (ix) *P. aconitifolius* (Dal moth)
- (x) *Trigonella foenum-graecum* (Fenugreek or Methi).

Leaves are used as source of vegetable. Seeds are used as spice

(xi) *Glycine max* (Soybean) : Seeds are **very rich in proteins** (42%). **Soya milk** is also prepared from it.

(xii) *Arachis hypogea* (Groundnut or Peanut or Moongphali).

(xiii) *Dolichos lablab* (Sem) : Vegetable

(xiv) *Lathyrus sativus* (Grass pea or Khesari dal)

(2) **Timber** : *Dalbergia sissoo* (Shisham or Indian red wood) and *D. latifolia* (Kali shisham or Indian rose wood or Indian baobab wood).

(3) **Ornamentals** : *Butea monosperma* (Palas or Dhak) : Deep red flowers and thus it is also called 'flame of the forest'

(4) **Other miscellaneous plants**

(i) *Indigofera tinctoria* (Indigo or Neel) : Indigo dye used in dyeing and printing cotton, is obtained from this plant.

(ii) *Abrus precatorius* (Ratti or Crab's eye) : Seed of this plant are used by jewellers for weighing purpose. Each seed is having constant weight of 1.75 grains.

□ Leaf juice used for cure of **leucoderma** (skin disease).

(iii) *Crotalaria juncea* (Sun hemp) : Fibres from **phloem** and **pericycle of stem** (bast fibres) are obtained used for making ropes, mats etc.

□ It is also important 'Green manure' crop.

## Solanaceae

### Systematic position

Division	: Angiospermae
Class	: Dicotyledonae
Subclass	: Gamopetalae
Series	: Bicarpellatae
Order	: Polymoniales
Family	: Solanaceae

**Habit** : Mostly herbs (*Petunia*, *Solanum nigrum*, *Nicotiana*, *Withania*), shrubs, a few trees (*Solanum grandiflorum* or potato tree) or climbers (*Solanum jasminoides* or potato vine, *Solanum dulcamara*).

**Root** : Branched tap root system.

**Stem** : Usually the stem is erect, solid, cylindrical and branched. Occasionally, it is spinous (*Solanum xanthocarpum*, *Datura stramonium*, *Lycium*). In potato (*Solanum tuberosum*) underground stem is modified into tubers.

**Leaves** : Cauline, ramal, exstipulate petiolate or sessile, alternate, sometimes opposite, simple, entire, pinnatisect in tomato (*Lycopersicum esculentum*). Venation unicostate reticulate, variegated in *Solanum jasminoides*.

**Inflorescence** : Axillary or extra axillary cyme. Solitary axillary in *Physalis* and *Pentunia*. Sub-sessile umbellate cyme in *Withania somnifera*, solitary in *Datura*.

**Flower** : Bracteate or ebracteate, pedicellate, complete, actinomorphic, rarely zygomorphic (e.g., *Salpiglossis*, *schizanthus*), bisexual, rarely unisexual (e.g., *Withania coagulans*) pentamerous, hypogynous.

**Calyx** : Sepals 5, gamosepalous, tubular or campanulate, persistent, accreant (enlarging in fruit, e.g., *Physalis*, *Withania*). Valvate or imbricate, green or coloured, hairy.

**Corolla** : Petals 5, gamopetalous, tubular or infundibuliform, valvate, twisted in *Datura*, bilabiate in *Schizanthus*, scale or hair like outgrowth may arise from the throat of the corolla tube, coloured.

**Androecium** : Stamens 5, rarely 4 (e.g., *Salpiglossis*) or 2 (e.g., *Schizanthus*), epipetalous, polyandrous alternate to petals, filament inserted deep in the corolla tube, anthers ditheous, usually basifixed or dorsifixed, introrse.

**Gynoecium** : Bicarpellary, syncarpous, ovary superior, carpels placed obliquely in diagonal plane, generally bilocular (2-4 locular in tomato, 4-locular in *Datura* due to false septa), placentation axile, ovules many in each locules, placentae swollen, a nectariferous disc or lobes may be present, stigma capitate or bifid.

**Fruit** : A many seeded berry (e.g., *Tomato*) or capsule (e.g., *Datura*).

**Seed** : Endospermic with straight or curved embryo.

**Floral formula** :  $\oplus \bar{\sigma} K_{(5)} \overline{C_{(5)}} \overline{A_5} \underline{G_{(2)}}$

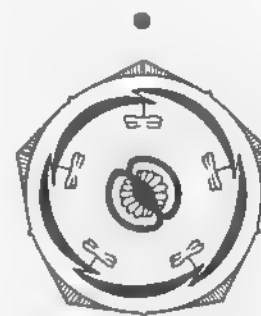


Fig : 2.1-24 Floral formula of Solanaceae (*Solanum nigrum*)

### Economic importance of the family.

#### (1) Medicinal plants

(i) *Datura stramonium* (*Datura* or Jimsonweed) : Drug 'Stramonium' is obtained from dried leaves and flowering tops, which is used in treatment of asthma. Atropine, hyoscyamine and hyocine alkaloids are also obtained from this.

Seeds of this plants are deadly poisonous.

(ii) *Atropa belladonna* (*Belladonna* or sag – Angoor) : **Roots** are source of an alkaloid – 'Atropine'

(iii) *Withania somnifera* (*Asgandha*) : Drug **Asgandh** is obtained from its roots, which is used in rheumatism, female troubles and cough.

(iv) *Hyoscyamus niger* (*Henbane*) : Drug **Henbane** is obtained from dried leaves and flowering tops, which is used for sedation and also in asthma and whooping cough.

#### (2) Food plants

(i) *C. frutescens* (*Shimla Mirch*)

(ii) *Capsicum annum* (*Chillies* or *Red pepper*)

(iii) *Lycopersicon esculentum* (*Tomato* or *Love apple*)

(iv) *Solanum melongena* (*Egg plant* or *Brinjal*)

(v) *Solanum tuberosum* (*Potato* or *Alu*)

(3) **Source of tobacco** : *Nicotiana tabacum* (*tobacco*) : It is source of alkaloid – 'Nicotin' and highest nicotine content is present in *Nicotiana rustica*.

**(4) Ornamentals**

(i) *Petunia alba*, *P. hybrida* : Flowers of different colours like white, pink etc.

(ii) *Cestrum nocturnum* (Night Jasmine or Rat Ki Rani).

(iii) *C. diurnum* (Day Jasmine or Din Ka Raja)

(iv) *Brunfelsia hopeana* (Yesterday, today, tomorrow plant).

(v) *Schizanthus* (Butterfly flower).

**(5) Others**

(i) *Solanum nigrum* (Night shade plant or Makoa).

**Malvaceae****Systematic position**

Division	: Angiospermae
Class	: Dicotyledonae
Subclass	: Polypetalae
Series	: Thalamiflorae
Order	: Malvales
Family	: Malvaceae

**Habit** : Plants are annual herbs (e.g., *Malva*, *Sida*, *Malvastrum*, *Urena*) shrubs (e.g., *Hibiscus rosa-sinensis*, *H. mutabilis*) or rarely trees (e.g., *Kydia*, *Bombax*).

**Root** : Branched tap root system.

**Stem** : Stem is erect, aerial, herbaceous or woody, usually solid, cylindrical and branched. Herbaceous portion of the stem is covered with stellate and scaly hairs; the woody part is fibrous. Plants usually have some mucilaginous substance.

**Leaves** : Leaves are alternate and stipulate (stipules 2, free lateral and often caducous). They are simple and petiolate, lamina is sometimes palmately lobed (e.g., *Gossypium*) or digitate (e.g., *Bombax*). Venation is multicostate reticulate.

**Inflorescence** : Usually the flowers are solitary axillary or terminal. Occasionally, they are in panicle raceme (e.g., *Kydia*).

**Flowers** : Flowers are bracteate or ebracteate, actinomorphic, bisexual (unisexual in *Kydia*), pentamerous and hypogynous. The number of bracteoles varies from 3 to many, they form a whorl of epicalyx below the calyx. Sometimes the epicalyx is absent (e.g., *Sida* and *Abutilon*).

**Calyx** : Sepals 5, gamosepalous (connate at the base but free at the tip) and show valvate aestivation. Usually epicalyx present.

**Corolla** : Petals 5, polypetalous (slightly fused at the base), usually adnate at the base to the staminal tube. They show twisted or imbricate aestivation.

**Androecium** : It has indefinite stamens. They are monadelphous. Filaments of the stamens are united to form a long staminal tube or staminal column which encloses the style. Basal part of the staminal tube is fused with the petals; thus stamens are epipetalous. Anthers are monothecous, reniform, transversely attached to the filament and extrorse. In *Bombax* stamens are polyadelphous.

**Gynoecium** : It is 2 to many carpellary. It is bicarpellary in *Plagianthus*, tricarpellary in *Kydia*, pentacarpellary in *Hibiscus* and *Sida*, ten carpellary in *Althaea rosea* and 15 – 20 carpellary in *Abutilon indicum*. All the carpels are fused (syncarpous) to form a single ovary. Ovary is superior, multilocular with one or more ovules in each chamber. The placentation is axile.

Style is usually long and enclosed in the staminal tube. Stigmas are as many as the number of carpels or double the number of carpels.

**Fruit** : Fruit is a loculicidal capsule (e.g., *Gossypium*, *Hibiscus*), schizocarpic capsule (e.g., *Abutilon*, *Sida*) or a berry (e.g., *Malvastrum*).

**Seed** : Seeds are albuminous. In *Gossypium* the seeds are pubescent, i.e., covered with hairs.

**Floral formula** :  $Br \oplus \overset{\circ}{\underset{\circ}{\text{E}}}_{(3-5)} K_{(5)} \overset{\circ}{\underset{\circ}{\text{C}}}_{(5)} \overset{\circ}{\underset{\circ}{\text{A}}}_{(5)} \underline{\text{G}}_{(2-5)}$



Fig : 2.1-25 Floral diagram of Malvaceae (*Hibiscus rosa sinensis*)

**Economic importance****(1) Fibre yielding plants**

(i) *Abutilon theophrasti* (Indian Mallow or China Jute) : This takes good dye and is extensively grown in China.

(ii) *Bombax malabaricum* Syn. *B. ceiba* (Semal or Kapok or silk cotton tree).

Woolly fibres from pericarp of fruits are source of **Kapok** or **Semal** or Silk cotton.

(iii) *Gossypium arboreum*, *G. herbaceum*, *G. hirsutum* (cotton): Cotton fibres are long hairs from seed epidermis.

(iv) *Hibiscus cannabinus* (Patsan or Deccanhemp)

**(2) Food plants**

(i) *Abelmoschus esculentus* Syn. *Hibiscus esculentus* (Lady's finger or bhindi or Okra) : Young fruits are used as favourite vegetable.

**(3) Ornamental plants**

(i) *Malva sylvestris* (Mallow) : An annual plant with purple rose flowers, is grown in gardens.

(ii) *Althaea rosea* (Hollyhock or Gulekhera) : Beautiful pink or red flowering plant

(iii) *Hibiscus rosa-sinensis* (China rose or shoe-flower or gurchal) : This is grown extensively as an ornamental plant with red or pink flowers.

**Cucurbitaceae****Systematic position**

Division	: Angiospermae
Class	: Dicotyledonae
Subclass	: Polypetalae
Series	: Calyciflorae
Order	: Passiflorales
Family	: Cucurbitaceae

**Habit** : These are trailing or climbing annuals or perennial herbs. Rarely they are shrubs (e.g., *Acanthosicyos*) or trees (e.g., *Dendrosicyos*).

**Stem** : Herbaceous, branched, pentangular, fistular, tendrils in axil of leaf or opposite to leaves. The morphological nature of tendril is of dispute.

**Leaves** : Leaves are cauline and ramal. They are alternate, exstipulate, simple, petiolate and cordate (e.g., *Cucurbita maxima*, *Coccinia grandis*) or deeply palmately lobed (e.g., *Luffa cylindrica*, *Cyclanthera pedata*). Venation is reticulate multicostate.

**Inflorescence** : Flowers are either solitary axillary (e.g., *Cucurbita*, *Coccinia*) or in cymose clusters (e.g., *Cucumis*, male flowers of *Luffa*).

Most of the members of the Cucurbitaceae are monoecious but a few are dioecious (e.g., *Coccinia cordifolia*, *Trichosanthes dioica*).

**Flower** : Flowers are bracteate or ebracteate, pedicellate, unisexual, incomplete actinomorphic, pentamerous and epigynous. *Schizopepon* is the only exception which has bisexual flowers.

**Male flower**

**Calyx** : Sepals 5, gamosepalous, quincuncial aestivation.

**Corolla** : Petals 5, gamopetalous, campanulate or rotate, imbricate or valvate aestivation.

**Androecium** : Stamens 5, polyandrous as in *Fevillea*, or (2)+(2)+1 as in *Momordica*, anthers twisted, alternate to petals, sometimes epipetalous, dehiscence longitudinal.

**Gynoecium** : Absent.

**Female flower**

**Calyx** : Similar to male flower.

**Corolla** : Similar to male flower.

**Androecium** : Absent but sometimes 2, 3 or 5 staminodes present.

**Gynoecium** : Tricarpellary, syncarpous, unilocular, ovary inferior, numerous ovules, parietal placentation but looks as axile placentation, style is simple, stigma 3.

**Fruit** : Pepo (variation of berry).

**Seeds** : Exalbuminous.

**Male flower** :  $Br$  or  $Ebr \oplus \sigma K_{(5)} C_{(5)} A_{(2)+(2)+1} \overline{G_0}$

**Female flower** :  $Br$  or  $Ebr \oplus \varnothing K_{(5)} C_{(5)} A_0 \overline{G_{(3)}}$



**Fig : 2.1-26 Floral diagram of Cucurbitaceae (*Cucurbita maxima* / Kaddu) (a) Floral diagram of male flower (b) Floral diagram of female flower**

**Economic importance of family****(1) Medicinal plants**

(i) *Coccinia indica* (Kandoori) : Extracts of root, leaf and fruit are used in treatment of diabetes.

(ii) *Citrullus colocynthis* (Indrayan) : **Colocynthis** alkaloid is obtained from its fruits, which is used in treatment of snake bite, rheumatism, etc

(iii) *Ecballium elatarium* : **Elatarium** is obtained from fruits, which is used in treatment of hydrophobia and malaria.

**(2) Vegetables**

(i) *Cucurbita maxima* (Great pumpkin or Vilayati Kaddu or Red pumpkin).

(ii) *C. moschata* (Pumpkin or Sitaphal)

(iii) *C. pepo* (Field pumpkin or Safed kaddu).

(iv) *Citrullus vulgaris* var. *Fistulosus* (Tinda or Dil pasand).

(v) *Lagenaria vulgaris* (Bottle gourd or Lauki).

□ Hollow, dried fruits of *Lagenaria siceraria* are used for making 'beens' (musical instruments) by snake charmers or 'saperas'.

(vi) *Luffa cylindrica* syn. *L. aegyptica* (Bath sponge or Ghia tori).

(vii) *L. acutangula* (Kali tori)

(viii) *Momordica charantia* (Bitter gourd or Karela).

(ix) *Trichosanthes anguina* (Snake gourd or Chichinda).

(x) *T. dioica* (Pointed gourd or Parwal).

**(3) Fruits**

(i) *Cucumis melo* (Kharbooza).

(ii) *Cucumis sativus* (Cucumber or Khira).

(iii) *Cucumis utlissimus* (Kakri)

(iv) *Cucumis melo* var. *momordica* (Phunt).

(v) *Citrullus vulgaris* (Water melon or Tarbooz).

(vi) *Benincasa hispida* (Ash gourd, Wax gourd or White gourd or Petha) – Famous sweet '**Petha**' is prepared from it.

□ Hollow dried fruits are used for making '**Sitar**'



**Compositae (Asteraceae)****Systematic position**

Division	: Angiospermae
Class	: Dicotyledonae
Subclass	: Gamopetalae
Series	: Inferae
Order	: Asterales
Family	: Compositae (Asteraceae)

(Largest family among the angiosperms)

**Habit** : Most of the plants are annual herbs (e.g., *Chrysanthemum*, *Lactuca*, *Calendula*, *Helianthus*, *Tagetes*). A few are shrubs (e.g., *Artemisia*, *Pluchea lanceolata*) or rarely trees (e.g., *Vernonia arborea*, *Wilkesia*, *Leucomeris*). *Milkamia cordata* is a twiner.

**Root** : Usually there is a tap root, but in *Dahlia* and *Taraxacum officinale* fasciculated roots are present.

**Stem** : Stem is usually herbaceous, erect, branched, solid, fibrous and sometimes with milky latex. In Jerusalem artichoke (*Helianthus tuberosus*) the stem is underground and tuberous. In *Baccharis*, it is winged like a leaf.

**Leaves** : Leaves are mostly alternate and occasionally opposite (e.g., *Helianthus*) or whorled (e.g., *Eupatorium*, *Zinnia verticillata*). They are exstipulate, petiolate, simple, pinnately or palmately lobed or compound (e.g., *Dahlia*, *Cosmos*). Venation is reticulate.

**Inflorescence** : Inflorescence is capitulum or head with an involucre of bracts at its base. The number of flowers in each inflorescence varies from 1000 (in large flowers of *Helianthus*) to 1 (in *Echinops*). Peduncle flat on which florets are attached.

**Flower** : Epigynous, usually pentamerous with reduction in certain whorls, hermaphrodite or unisexual complete or incomplete, tubular (actinomorphic) or ligulate (zygomorphic), bracteate or ebracteate.

(1) **Ray florets** : Towards periphery of head, sessile bracteate, pistillate or neutral, zygomorphic, ligulate, epigynous.

**Calyx** : Absent or hairy pappus or scaly, persistent.

**Corolla** : Petals 5, gamopetalous, ligulate, strap shaped.

**Androecium** : Absent

**Gynoecium** : Bicarpellary, syncarpous, ovary inferior, unilocular, one ovule in each locule, basal placentation, style simple narrow, stigma branched.

(2) **Disc florets** : In the centre of head, bracteate, bisexual, actinomorphic, tubular, pentamerous, epigynous.

**Calyx** : Absent or pappus.

**Corolla** : Petals 5, gamopetalous, tubular.

**Androecium** : 5 stamens, epipetalous, syngenesious, ditheous, bilobed, introrse, filament free.

**Gynoecium** : Bicarpellary, syncarpous, ovary inferior, unilocular, single ovule in the locule, basal placentation, style single, short, stigma bifid.

(3) **Neutral florets** : Androecium and gynoecium both are absent. Remaining structures are similar to ray floret and disc florets.

**Fruit** : Cypsella.

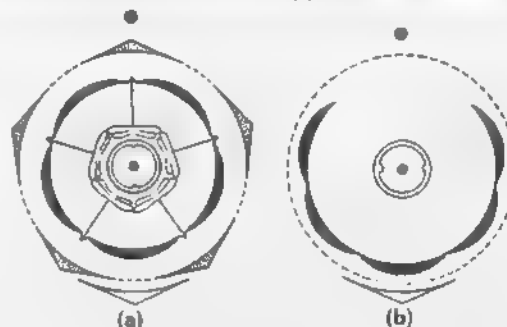
**Seed** : Exalbuminous.

**Floral formula** :

**Ray florets** :  $Br. \% \text{ } \overline{\text{K}_0} \text{ or } PC_{(5)} A_0 \overline{G_{(2)}}$

**Disc florets** :  $Br. \% \text{ or } \oplus \overline{\text{K}_0} \text{ or } PC_{(5)} A_{(3)} \overline{G_{(2)}}$

**Neutral florets** :  $\% \text{ or } \oplus \overline{\text{K}_0} C_{(5)} A_0 G_0$



**Fig : 2.1-27 Floral diagram of Compositae (*Helianthus annuus*)**  
(a) Ray floret, (b) Disc floret

**Economic importance of the family****(1) Sources of medicines**

(i) *Arnica montana* : This plant yields 'Arnica', which is used as hair vitalizer.

(ii) *Eclipta prostrata* (bhringraj) : Its extract is used as hair tonic.

(iii) *Artemisia cina* or *A. maritima* (worm weed) : A wormicide (anthelmintic) 'Santonin' is obtained from dried unopened flower heads, which is used as vermifuge or in expelling the intestinal worms.

(iv) *Taraxacum officinale* (Common dandelion) : Drug 'Taraxacum' obtained from roots and rhizomes is used as laxative and liver tonic.

(v) *Calendula officinalis* : 'Calendula' drug obtained from dried ligulate florets is used in sprains.

**(2) Sources of food**

(i) *Lactuca sativa* (Garden lettuce or Salad) : This is a salad crop and leaves provide a valuable salad throughout the world.

(ii) *Cichorium intybus* (Chicory or Kasni) : Roots are source of 'Chicory powder', which is used for blending coffee.

(iii) *Helianthus tuberosus* (Jerusalem artichoke or Hathichuk) : The tubers are source of food or vegetable (having plenty of Inulin).

**(3) Sources of oils**

(i) *Carthamus tinctorius* (Safflower or Kusum) : Seeds yield oil which is edible and because it has percentage of unsaturated fatty acid, so it is very good for heart patients.

(ii) A red dye 'Kusum' is also obtained from its flowers, which is used in foods as well as clothes.

**(4) Sources of rubber**

(i) *Taraxacum kok-saghyz* (Russian dandelion) : Roots contain latex, which is the source of 'Dandelion rubber.'

(ii) *Parthenium argentatum* In America, Guayule rubber, is obtained from this plant, because 'caoutchouc' granules are present in plant body.

**(5) Sources of insecticide**

(i) *Chrysanthemum marshallii* and *C. cinerariaefolium* (Guldaodi) : Flower heads are source of a commercial insecticide 'Pyrethrum'.

**(6) Ornamentals**

(i) *Calendula officinalis* (Pot marigold)

(ii) *Chrysanthemum* spp. (Guldaodi)

(iii) *Tagetes* spp. (Marigold or Genda)

(iv) *Helianthus annuus* (Sunflower)

## Gramineae or Poaceae

The members of this family are commonly known as 'grasses'.

Plants are mostly herbs having stem with marked solid nodes and hollow internodes, i.e., **stem is culm**. Further stem is generally circular and hollow.

Leaves simple, alternate, with sheathing bases and ligulate (i.e., a membranous outgrowth '**ligule**' is present at junction of leaf sheath and leaf lamina).

Spikelet (not flower) is the unit of inflorescence, which may be arranged in spike or panicle, i.e. inflorescence is spike of spikelets or panicle of spikelets.

Each spikelet is having 1 – 5 flowers on a reduced axis, which bear two leaf like structures (**glumes**) at base

Each flower is in axil of other like structure called '**lemma**' (bract). On the flower axis is another leaf-like structure called **palea** (bracteole). Above **palea** are two scale like **lodicules** (perianth).

Flower is hypogynous and zygomorphic.

Perianth reduced and represented by lodicules.

Generally 3 stamens with dithecous and **versatile** anthers.

Carpel is generally 1, unilocular ovary with basal placentation, 2 long styles ending in **feathery stigmas**.

Fruit is **karyopsis** or **grain** (single seeded indehiscent fruit, in which seed coat fuses with fruit wall to form husk).

## F.F. (Floral Formula)

$$\text{Br. Brl.} + \sigma^+ P_2 (\text{lodicules}) \overset{\text{or}}{A_3 G_1} \underset{3+3}$$

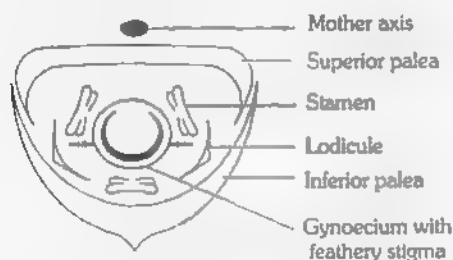


Fig : 2.1-28 Floral Diagram of *Triticum aestivum* (Wheat)

## (1) Cereals and millets

Most important source of food in the world is cereals having **karyopsis** or **grain fruit**, e.g., *Triticum vulgare* (Wheat), *Zea mays* (Maize), *Oryza sativa* (Rice), *Avena sativa* (Oat), *Hordeum vulgare* (Barley).

Small sized grains constitute millets, which also provide food, e.g., *Sorghum vulgare* (Jawar), *Pennisetum typhoides* (Bajra), *Eleusine coracana* (Ragi or Mandua).

(2) Source of Sugar : *Saccharum officinarum* (Sugar cane)

## (3) Other plants

(i) *Dendrocalamus* sps : Both (i) and (ii) **provide bamboo**

(ii) *Cynodon dactylon* (Doob grass) : Fodder.

(iii) *Andropogon muricatus* (Khas) : Roots provide khas oil.

## Tips &amp; Tricks

✍ Culms : Their nodes and internodes are extremely clear ; internodes are hollow, e.g., *Bambusa*.

✍ Roots arising from callus in tissue culture are adventitious.

✍ Life of root hairs is hardly one week. During transplantation, root hairs are shed and therefore, plant remains wilted for sometime till the formation of new root hairs.

✍ Roots provide more than 50% of total food.

✍ Acaulescent. Having a reduced stem.

✍ Allyl sulphide. Characteristic smell of Onion and Garlic.

✍ The anticancerous substance in garlic is gemium.

✍ Stem is quadangular in *Ocimum*, triangular in *Cyperus*, ribbed in *Cucurbits* and flat in *Cactus*

✍ Petiole develops last in the leaf.

✍ CTC tea leaves are rich in iron because they are cured in iron pans.

✍ Plant with single leaf is *Monophyllea*.

✍ Plant with two leaves only in *Welwitschia*.

✍ Smallest leaf : *Wolffia*.

✍ Broadest leaf : *Victoria amazonica* (diameter 5 to 6 feet).

✍ Longest leaf : *Raphia vinifera* (30 to 50 feet).

✍ Largest leaf : *Victoria regia* is the largest leaf of plant kingdom, which are 4m in radius and diameter is 1.5 – 1.8 m.

✍ Anisophily : Presence of 2 types of leaves on same node of the plant of *Boerhaavia*

✍ Belt's corpuscles, glands producing edible materials at the apices of leaflets in *Acacia sphaerocephala*.

✍ Spike is most common inflorescence.

✍ Capitulum (racemose head) is most evolved/highly advanced.

✍ Longest inflorescence : *Agave* (12m), *amorphophallus* (5.5m). *puyaraimondil* (10 metres).

✍ Cauliflory : The condition of developing flowers on the main stem (trunkiflory) or older branches from old or persisting axillary buds is called cauliflory. e.g., *Ficus*.

✍ Intersexual : Perfect hermaphrodite, androgynous or monodinous flower.

✍ Trioecious : Three types of plants – male, female and monoecious, e.g., *Silence*.

✍ Longest stigma and style – Maize

✍ Style and stigma of saffron (crocus) are edible and source of kesar.

✍ Ripeness of a flower depends on minimum number of leaves.

✍ Heterostyly : In this condition, stamens, style and stigma are of different heights. e.g., *Primula*, *Oxalis*.

✍ Plants of tropics bear naked buds i.e., buds without covering.

✍ Recalcitrant seeds : The seeds get killed on reduction of moisture and exposure to low temperature. e.g., Tea, Jack fruit.

✍ Orthodox seeds : The seeds which can be stored for long as they tolerate reduction in moisture content (upto 5%) exposure to

low temperature and anaerobic conditions, e.g., Legumes, cereals.

Smallest seed is of *Orchis* (wt. 0.004 g) and 1 gram contains 20 lakh seeds.

Largest seed is Double coconut (Fresh wt. 6 kg).

Seeds constitute 70% of our diet.

Largest fruit / Largest seed is *Lodoicea maldivica*.

All modern classifications are based on evolution, genotypes and ecological characters. They are phylogenetic in nature.

Presence of myrosin enzyme is chief feature of family brassicaceae.

## Ordinary Thinking

### Objective Questions

#### Root

- If a primary root continues to grow, the type of root system will be known as [NCERT; DUMET 2009]
  - Secondary
  - Fibrous
  - Tap
  - Stilt
- Pneumatophores occur in plants of [CBSE PMT 2000]
  - Sandy soil
  - Saline marshy soil
  - Marshy soil
  - Water
- Roots developing from plant parts other than radical are [NCERT; Chd. CET 1997; HPMT 2005]
  - Epiphyllous
  - Epicaulous
  - Adventitious
  - Fibrous
- In which the pneumatophores are found [NCERT; BVP 2001; AMU (Med.) 2009]
  - Tinospora*
  - Pinus*
  - Rhizophora*
  - None of these
- Outer covering of epiphytic root is [CPMT 2001; Odisha JEE 2005]
  - Osmophore
  - Rhizophore
  - Velamen
  - Pneumatophore
- Which of the following is correctly matched [AIIMS 2012]
  - Monstera* – Fibrous root
  - Dahlia* – Fasciculated root
  - Azadirachta* – Adventitious root
  - Basil* – Prop roots
- Conical fleshy roots occur in
  - Sweet potato
  - Dahlia*
  - Asparagus*
  - Carrot
- Napiform roots are recorded from
  - Radish
  - Carrot
  - Beet
  - Sweet potato
- Fusiform roots are found in [BHU 1996]
  - Solanum tuberosum*
  - Calocasia*
  - Daucus carota*
  - Raphanus sativus*
- A fibrous root system is better adapted than tap root system for [BHU 1993, 2001; AMU (Med.) 2001; DUMET 2009]
  - Storage of food
  - Anchorage of plant to soil
  - Absorption of water and minerals
  - Transport of water and organic food
- Stilt roots are reported from [Bihar PMT 1994; BHU 1996; Odisha JEE 1997, 2012]
  - Pandanus* (Screw Pine)
  - Radish
  - Mango-ginger
  - Bryophyllum*
- Assimilatory (Photosynthetic) roots a characteristic of [Kerala CET 2000; BHU 2012]
  - Trapa* and *Tinospora*
  - Taeniophyllum* and *Podostemon*
  - Both correct
  - None of these
- Root cap is largest in
  - Banyan
  - Pandanus*
  - Jussiaea*
  - Maize
- Find the incorrect match [AMU (Med.) 2010]
  - Tap root : Carrot
  - Adventitious root : Sweet potato
  - Prop root : Banyan tree
  - Stilt root : Turnip
- A root is adventitious when it is [CPMT 2002; RPMT 2005]
  - Swollen
  - Growing in marshy places
  - Formed from plumule
  - Modified for storage
- Monocot plants are characterized by the presence of [NCERT; J & K CET 2005]
  - Tap roots
  - Fibrous roots
  - Annulated roots
  - Stilt roots
- Nodulated roots bearing family is [RPMT 1993, 95, 96]
  - Mimosoideae
  - Caesalpinoideae
  - Papilionatae
  - Solanaceae
- Clinging and epiphytic roots are found in [CBSE PMT 1999]
  - Orchid
  - Tinospora* / *Trapa*
  - Rhizophora* / *Pandanus*
  - Pothos* / *Podostemon*
- Roots are absent in
  - Myriophyllum*
  - Ceratophyllum*
  - Utricularia* and *Wolffia*
  - All of these
- Stilt roots which grow obliquely from basal nodes of culm stem and acting as brace are found in [NCERT; MP PMT 1993; DPMT 1999]
  - Sorghum
  - Maize
  - Sugarcane
  - All of these
- In *Ipomoea batatas*/Sweet potato the food is stored in [Bihar PMT 1994; JKCEE 2002]
  - Root tuber
  - Stem tuber
  - Bud
  - Leaves
- In maize, the fibrous roots develop from [NCERT]
  - Lower nodes
  - Upper nodes
  - Upper internodes
  - None of the above
- Select the correct statements
  - From the region of elongation, some of the epidermal cells for root hairs
  - Pneumatophores are seen in *Rhizophora*
  - Adventitious roots are seen in the Banyan tree
  - Maize and sugarcane have prop roots

[NCERT; Kerala PMT 2011]

  - (A) and (D)
  - (A), (C) and (D)
  - (C) and (D)
  - (B) and (C)
  - (A), (B) and (D)

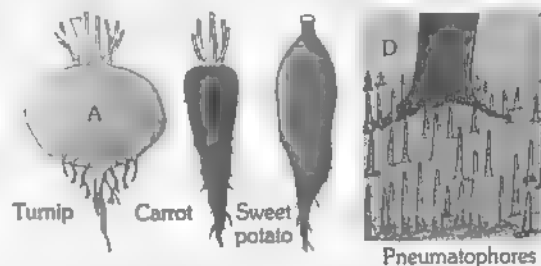
24. Regions of root from base to root tip are  
[NCERT; AMU (Med.) 2001]  
(a) Maturation zone — Cell division zone — Elongation zone  
(b) Maturation zone — Elongation zone — Cell division zone  
(c) Cell division zone — Elongation zone — Maturation zone  
(d) Elongation zone — Cell division zone — Maturation zone
25. Leguminous plants possess [RPMT 1993]  
(a) Napiform roots (b) Nodulated roots  
(c) Tuberous roots (d) Fusiform roots
26. Match the items in Column – I with Column – II and choose the correct alternative

Column – I		Column – II	
A.	Tubercular storage roots	1.	<i>Tinospora</i>
B.	Pneumatophores	2.	<i>Heritiera</i>
C.	Hauatoria	3.	<i>Asparagus</i>
D.	Prop-roots	4.	<i>Viscum</i>
E.	Assimilatory roots	5.	<i>Screw pine</i>

[Kerala PMT 2007]

- (a) A–2, B–3, C–4, D–5, E–1  
(b) A–3, B–4, C–5, D–1, E–2  
(c) A–3, B–1, C–2, D–5, E–4  
(d) A–5, B–4, C–5, D–2, E–1  
(e) A–3, B–2, C–4, D–5, E–1
27. Which of the following plant parts can respire even in the absence of oxygen [KCET 2006]  
(a) Seeds (b) Roots  
(c) Stems (d) Leaves
28. Roots play insignificant role in absorption of water in [AIPT 2015]  
(a) Pistia (b) Pea  
(c) Wheat (d) Sunflower
29. Velamen takes part in [Bihar PMT 1994]  
(a) Absorption of moisture from air  
(b) Absorption of water from soil  
(c) Exchange of gases  
(d) Transpiration
30. Sweet potato is modification of [J & K CET 2005]  
(a) Leaf (b) Root  
(c) Stem (d) Flowering axis
31. Which is not a product of root [NCERT; CPMT 1993; MP PMT 2013]  
(a) Sugarbeet (b) Carrot  
(c) Radish (d) Potato
32. Aerial absorptive roots occur in [Odisha JEE 1995]  
(a) Epiphytes (b) Mesophytes  
(c) Hydrophytes (d) Xerophytes
33. Epiphytes like *Vanda* develop special layer of absorptive tissue velamen consisting of 4 or 5 layers of long polygonal cells. Velamen is formed by [BHU 1996; AIIMS 2001]  
(a) Absorbing roots (b) Stem  
(c) Clinging roots (d) Hanging roots

34. Climbing roots occur in [APMEE 1996; CBSE PMT 1999]  
(a) *Vanilla* (b) *Piper betle*  
(c) Both (a) and (b) (d) *Taeniophyllum*
35. A rootless angiosperm is  
(a) *Cuscuta* (b) *Balanospora*  
(c) *Utricularia* (d) All of these
36. Reproductive roots taking part in reproduction are found in  
(a) *Dalbergia* (Shisham) (b) *Dahlia*  
(c) Sweet Potato (*Ipomoea*) (d) All of these
37. See the following diagrams



Which of the following is not correct about A, B, C and D

[NCERT]

- (a) A, B and C are underground roots but D grows vertically upwards  
(b) Pneumatophore is found in the plants that grow in sandy soil  
(c) Pneumatophores help to get oxygen for respiration  
(d) Tap roots of carrot, turnip and adventitious root of sweet potato, get swollen and store food
38. Buttress roots are  
(a) Aerial (b) Underground  
(c) Aquatic (d) Horizontal
39. Root which grow from branches of Banyan tree are [Odisha JEE 2005]  
(a) Breathing roots (b) Climbing roots  
(c) Hanging roots (d) Prop roots
40. Pneumatophores are useful in [NCERT; CPMT 1993, 96]  
(a) Respiration (b) Transpiration  
(c) Guttation (d) Protein synthesis
41. Pneumatophores are characteristics of family [NCERT; Bihar PMT 2001]  
(a) Loranthaceae (b) Hydrocharitaceae  
(c) Rhizophoraceae (d) Orchidaceae
42. There is maximum growth in root [AFMC 1993; CPMT 1998]  
(a) In the dark (b) In the light  
(c) At the root apex (d) Just behind the root apex
43. Prop roots of Banyan tree are meant for  
(a) Respiration  
(b) Absorption of water from soil  
(c) Retention of water in soil  
(d) Providing support to big tree
44. Roots have thorny branches in  
(a) *Vanilla* (b) *Asparagus*  
(c) *Acanthorhiza* (d) *Pothos*

45. Haustoria or sucking roots occur in [BHU 1996; DPMT 1999; JIPMER 1999; Pb. PMT 1999; Kerala PMT 2006]  
(a) Betel (b) Orchids  
(c) *Cuscuta* (d) *Tinospora*
46. Pneumatophores or breathing roots occur in / Respiratory roots and vivipary reproduction are the characteristic of [CPMT 1993; APMEE 1999; AMU (Med.) 2006; RPMT 2006]  
(a) Hydrophytes (b) Epiphytes  
(c) Xerophytes (d) Mangrove plants
47. Which is not a stem modification  
(a) Ginger (b) Mango-ginger  
(c) Potato (d) Garlic
48. Food is stored in one of the following [Kerala CET 2001]  
(a) Respiratory root (b) Fibrous root  
(c) Fasciculated root (d) Nodulated root
49. White spongy floating roots occur in  
(a) *Trapa* (b) *Nymphaea*  
(c) *Eichhornia* (d) *Jussiaea*
50. Sweet potato is homologous to [NCERT; CBSE PMT (Mains) 2011]  
(a) Ginger (b) Turnip  
(c) Potato (d) *Colocasia*
51. Which of the following groups of plants are propagated through underground root [Kerala PMT 2006]  
(a) *Bryophyllum* and *Kalanchoe*  
(b) Ginger, potato, onion and zamikand  
(c) *Pistia*, *chrysanthemum* and pineapple  
(d) Sweet potato, asparagus, tapioca and dahlia  
(e) Agave, wild jam and oxalis
52. Root pocket occurs in  
(a) Maize (b) *Pandanus*  
(c) *Banyan* (d) Water Hyacinth

### Stem

1. In *Amorphophallus* and *Colocasia* (Arroids) an extremely enlarged underground vertical stem meant for vegetative reproduction and storage is [DPMT 1994; AFMC 1996, 2010]  
Or  
Modified stem present in *Gladiolus* is [Odisha JEE 2004]  
(a) Tuber (b) Corm  
(c) Bulb (d) Rhizome
2. Vegetative reproduction occurs by bulbil in  
(a) Agave (b) *Colocasia*  
(c) *Zingiber* (d) *Vallisneria*
3. Stem is modified into cladode in [J & K CET 2008]  
Or  
One of single internodal branches are found in  
(a) *Casuarina* (b) Asparagus  
(c) *Opuntia* (d) *Euphorbia*
4. Find out correct order of vegetative propagules of plants like potato, ginger Agave, *Bryophyllum* and water hyacinth [Kerala PMT 2012; AIPMT (Cancelled) 2015]  
(a) Offset, bulbil, leaf bud, rhizome and eyes  
(b) Leaf bud, bulbil, offset, rhizome and eyes  
(c) Eyes, rhizome, bulbil, leaf bud and offset  
(d) Rhizome, bulbil, leaf bud, eyes and offset  
(e) Offset, bulbil, leaf bud, rhizome and eyes
5. Accessory buds occur at  
(a) Stem tip (b) Branch tip  
(c) Leaf axil (d) Side of axillary bud
6. Floral bud tendril is found in [BHU 1997; JIPMER 1997]  
(a) *Antigonon* (b) *Smilax*  
(c) Rose (d) *Bryophyllum*
7. Thorn is a stem structure because it [NCERT; CPMT 1995; Kerala PMT 2004]  
(a) Develops from trunk  
(b) Develops from axillary bud  
(c) Grows from external surface  
(d) Is pointed
8. Which of the following statements is/are true  
(A) If the stem is jointed with solid nodes and hollow internodes, it is called caudex  
(B) In *Tridax* the stem is decumbent  
(C) Corm is a condensed form of rhizome growing more or less in vertical direction  
(D) Sucker is an underground modification of stem  
(E) Biparous type of cymose branching is seen in *Saraca* [Kerala PMT 2008]  
(a) (A), (D) and (E) only (b) (B) and (C) only  
(c) (B), (C) and (E) only (d) (C) and (D) only  
(e) (D) and (E) only
9. An example of edible underground stem is [NCERT; CPMT 1993; HPMT 2005; CBSE PMT 2014]  
(a) Sweet potato (b) Potato  
(c) Carrot (d) Groundnut
10. In hook climber *Artabotrys*, the hooks are modified  
(a) Petioles (b) Axillary shoots  
(c) Leaves (d) Inflorescence axis
11. In *Opuntia*, the function of photosynthesis is carried out by [NCERT; AFMC 1996; J & K CET 2010]  
(a) Cladode (b) Phylloclade  
(c) Phyllode (d) Bulb
12. An underground specialised shoot with reduced disc like stem covered by fleshy leaves is [APMEE 1996; JKCME 2000; AIIMS 2013]  
(a) Bulb (b) Bulbil  
(c) Rhizome (d) Rhizophore

13. A horizontal underground stem is a  
[Tamilnadu 2001; DUMET 2009]  
Or  
Ginger plant has an underground stem which is [CPMT 1994;  
JIPMER 1998; MP PMT 2004; J & K CET 2005]  
(a) Corm (b) Phylloclade  
(c) Rhizome (d) Rhizoid
14. The structure which contain vascular bundle and is modification of stem is [AFMC 2010]  
(a) Bristles (b) Thorn  
(c) Prickle (d) Spine
15. Potato is (underground) stem because it [Odisha JEE 1995]  
(a) Possesses axillary buds (Eyes)  
(b) Lacks chlorophyll  
(c) Does not bear roots  
(d) Contains reserve food
16. New Banana plants develop from [CBSE PMT 1990; AMU (Med.) 2012]  
(a) Rhizome (b) Sucker  
(c) Stolon (d) Seed
17. Stem may function for [AMU (Med.) 2009]  
(a) Storage, support and vegetative propagation  
(b) Protection  
(c) Spread branches  
(d) All of these
18. Which one of the following is a xerophytic plant in which the stem is modified into the flat green and succulent structure [CBSE PMT (Maine) 2010; Kerala PMT 2012]  
Or  
Phylloclade is found in [AMU (Med.) 2001]  
(a) *Opuntia* (b) *Casuarina*  
(c) *Hydrilla* (d) *Acacia*
19. Largest bud is of  
(a) Cabbage (b) Cauliflower  
(c) Agave (d) Onion
20. Which one of the following is correctly matched [NCERT; CBSE PMT (Pre.) 2012]  
(a) Onion–Bulb  
(b) Ginger–Sucker  
(c) *Chlamydomonas* – Conidia  
(d) Yeast – Zoospores
21. Bulb is modified [Bihar PMT 1994]  
(a) Leaf (b) Shoot  
(c) Root (d) Flower
22. Succulent stem is found in [Odisha JEE 2010]  
(a) *Pisum* (b) *Casuarina*  
(c) *Oxalis* (d) *Euphorbia*
23. Eye of potato is [NCERT;  
CBSE PMT 2001; CBSE PMT (Pre.) 2011]  
(a) Apical bud (b) Axillary bud  
(c) Accessory bud (d) Adventitious bud
24. Which of the following is not related to corm [Kerala CET 2001]  
(a) Tunic (b) Lateral buds  
(c) Nodes (d) Scale leaves
25. Thorns differ from prickles in having  
(a) Vascular supply (b) Endogenous origin  
(c) Bark (d) All of these
26. *Mentha* (Mint) has one of the following  
(a) Sucker (b) Offset  
(c) Stolon (d) Rhizome
27. Stem tendrils occur in [Odisha JEE 2000]  
(a) *Smilax* (b) *Gloriosa*  
(c) *Vitis* (d) *Lathyrus*
28. Green leaf-like one internode long stem branches are called [KCET 2003; Odisha JEE 2012]  
(a) Phylloclades (b) Phyllodes  
(c) Bulbils (d) Cladodes
29. Which of the following is the subaerial stem modification with long internode [Odisha JEE 2011]  
(a) Rhizome (b) Offset  
(c) Runner (d) Sucker
30. Rhizome which grows vertically upwards are [AFMC 2005]  
(a) Corms (b) Stolon  
(c) Bulbils (d) Root stock
31. Thorn of *Bougainvillea* is modified [NCERT; NEET 2017; Bihar PMT 1994]  
(a) Stem (b) Leaf  
(c) Floral bud (d) Root
32. Ginger is a stem which can be differentiated from root because it [MP PMT 2007]  
(a) Grows parallel to ground  
(b) Stores food  
(c) Lacks chlorophyll  
(d) Has nodes and internodes
33. Which is not a rhizome [Pb. PMT 1997]  
(a) *Colocasia* (b) Lotus  
(c) Ginger (d) Turmeric
34. In *Passiflora*, the tendrils are modified  
(a) Axillary buds (b) Upper leaflets  
(c) Whole leaves (d) Stipules
35. Thorns with leaves and flowers are found in [APMEE 2002]  
(a) *Bougainvillea* (b) *Carissa*  
(c) *Duranta* (d) *Artabotrys*
36. Stem takes part in storage and perennation in [DPMT 1994;  
AMU (Med.) 1994; AFMC 1994; Manipal 1997]  
(a) Wheat (b) Groundnut  
(c) Radish (d) Ginger
37. Prickles of Rose are  
(a) Modified leaves (b) Modified stipules  
(c) Exogenous in origin (d) Endogenous in origin

38. Match the following and select the correct combination from the options given below

Column I (Stem Modifications)		Column II (Found in)	
A.	Underground stem	1.	<i>Euphorbia</i>
B.	Stem tendril	2.	<i>Opuntia</i>
C.	Stem thorns	3.	Potato
D.	Flattened stem	4.	<i>Citrus</i>
E.	Fleshy cylindrical stem	5.	Cucumber

[NCERT; Kerala PMT 2011]

- (a) A-1, B-2, C-3, D-5, E-4  
 (b) A-2, B-3, C-4, D-5, E-1  
 (c) A-3, B-4, C-5, D-1, E-2  
 (d) A-3, B-5, C-4, D-2, E-1  
 (e) A-5, B-3, C-4, D-1, E-2
39. Bulbil is a modification of  
 (a) Underground stem (b) Bases of leaves  
 (c) Buds (d) Radicle
40. Which of the following is **not** a stem modification  
 [NEET (Phase-I) 2016]  
 (a) Pitcher of *Nepenthes*  
 (b) Thorns of citrus  
 (c) Tendrils of cucumber  
 (d) Flattened structures of *Opuntia*
41. In humid climate, presence of spines in shrubs is  
 (a) To reduce transpiration  
 (b) To defend against mammal herbivory  
 (c) To defend against wood cutters  
 (d) To check seed predation by birds
42. In onion leaves food is stored in the form of  
 (a) Sugar (b) Starch  
 (c) Protein (d) Malic acid
43. The cloves which are used in food preparation are  
 [Kerala CET 2005; Odisha JEE 2010]  
 (a) Seeds (b) Leaves  
 (c) Flower buds (d) Stem tip  
 (e) Terminal bud
44. Rhizomes are mostly  
 [AFMC 1999]  
 (a) Sympodial (b) Diageotropic  
 (c) Horizontal (d) All of these
45. Tip of twiner is sensitive and coils around support itself. This coiling is called  
 (a) Nutation (b) Vernation  
 (c) Epinasty (d) Circination
46. Multicellular hairs are found on  
 [MHCET 2004]  
 (a) Root (b) Stem  
 (c) Both (a) and (b) (d) None of the above
47. Potato and sweet potato  
 [AIIMS 2004]  
 (a) Have edible parts which are homologous organs  
 (b) Have edible parts which are analogous organs  
 (c) Have been introduced in India from the same place  
 (d) Are two species of the same genus

48. Which of the following plants have long slender and coiled stem tendrils developed from axillary buds  
 [NCERT; Kerala PMT 2011]

- (a) Grapevine and pumpkins  
 (b) Australian *Acacia* and watermelon  
 (c) *Bougainvillea* and cucumber  
 (d) Strawberry and grapevine  
 (e) *Alstonia* and pumpkins

49. Aroids store food in  
 (a) Inflorescence (b) Enlarged root  
 (c) Leaf bases (d) Swollen stem
50. Which one of the following pairs is wrongly matched while the remaining three are correct [CBSE PMT (Malina) 2011]  
 (a) *Bryophyllum*-Leaf buds (b) *Agave* - Bulbils  
 (c) *Penicillium* - Conidia (d) Water hyacinth - Runner
51. Stem modified for photosynthetic function by appearing like leaves are known as [NCERT; AFMC 1996; JIPMER 1998; JKCME 2002; MP PMT 2013; NEET (Phase-I) 2016]

Or

Leaves are changed into spines in xerophytic structures

Called [CPMT 1996; Kerala PMT 2004]

- (a) Phyllode (b) Phylloclade  
 (c) Cladode (d) Tendril

52. Which one of the following statements is **not** correct  
 [NEET (Phase-II) 2016]  
 (a) Water hyacinth, growing in the standing water, drains oxygen from water that leads to the death of fishes  
 (b) Offspring produced by the asexual reproduction are called clone  
 (c) Microscopic, motile asexual reproductive structures are called zoospores  
 (d) In potato, banana and ginger, the plantlets arise from the internodes present in the modified stem

### Leaf

1. Petiole part of the leaf is known as [Odisha JEE 2012]  
 (a) Epipodium (b) Mesopodium  
 (c) Hypopodium (d) None of these
2. A leaf is identified from [JKCME 1999]  
 (a) Flat green lamina  
 (b) Presence of leaf blade and petiole  
 (c) Presence of axillary bud  
 (d) Occurrence of chlorophyll
3. Find the correct match [AMU (Med.) 2010]  
 (a) Mustard plant : leaves are opposite  
 (b) Mustard plant : leaves are alternate  
 (c) Guava plant : Leaves are alternate  
 (d) Guava plant : Leaves are whorled
4. Finely dissected leaves occur in  
 (a) Free floating plants  
 (b) Rooted floating leaved plants  
 (c) Submerged plants  
 (d) Emerged plants

5. In Tamarind (Imli) the pinnate leaf is [Bihar PMT 1994]  
 (a) Tripinnate (b) Bipinnate  
 (c) Paripinnate (d) Imparipinnate
6. Presence of sheathing leaf base and ligule are characteristic of [NCERT; Chd. CET 1997]  
 (a) Cycas leaf (b) Fern leaf  
 (c) Banana leaf (d) Grass leaf
7. Approximate diameter of *Victoria* leaf is [BHU 1996]  
 (a) 1m (b) 1.3m  
 (c) 2m (d) 3m
8. A dicotyledenous plant showing parallel venation is  
 (a) *Dioscorea* (b) *Smilax*  
 (c) *Calophyllum* (d) *Hibiscus*
9. Bipinnate leaves are characteristic of  
 (a) Cruciferae (b) Solanaceae  
 (c) Papilionoideae (d) Mimosoideae
10. In *Lathyrus aphaca*, the leaves are modified into [AIIMS 1997]  
 (a) Spine (b) Tendril  
 (c) Scale (d) Stem-like structure
11. Foliose stipules are found in [Odisha JEE 2012]  
 (a) Rose (b) Wild pea  
 (c) Castor (d) Kadam
12. In sweet pea, the tendrils are modified [JIPMER 2000; RPMT 2002]  
 (a) Stem branches (b) Leaflets  
 (c) Leaves (d) Stipules
13. Bud scales of *Ficus* are modified  
 (a) Leaves (b) Stipules  
 (c) Stem (d) Prickles
14. Imparipinnate leaf is the one where  
 (a) Leaflets are borne in pairs  
 (b) Leaflets are small  
 (c) Leaflets are large  
 (d) Rachis is terminated by an odd leaflet
15. Identify the correct types of phyllotaxy which shown in the following figures [NCERT]
- A                      B                      C
- (a) A – Whorled, B – Alternate, C – Opposite  
 (b) A – Alternate, B – Whorled, C – Opposite  
 (c) A – Whorled, B – Opposite, C – Alternate  
 (d) A – Alternate, B – Opposite, C – Whorled
16. A simple leaf is present in  
 (a) Peepal (b) *Mimosa*  
 (c) Neem (d) All of these
17. Phyllotaxis is [NCERT; AIIMS 1996; APMEET 1999; Kerala CET 2002]  
 (a) Mode of leaf arrangement on stem  
 (b) Types of roots  
 (c) Arrangement of sepals and petals in a flower  
 (d) Type of ovary
18. Tendrillar stipules occur in [DPMT 1999]  
 (a) *Dolichos lablab* (b) *Acacia*  
 (c) *Smilax* (d) Mango
19. The leaves are modified into tendrils, hooks, pitcher and bladder in the following plants respectively [Kerala PMT 2006]  
 (a) Sweet pea, Cat's nail, *Nepenthes*, *Utricularia*  
 (b) Sweet pea, Cat's nail, *Utricularia*, *Nepenthes*  
 (c) *Nepenthes*, Cat's nail, Sweet pea, *Utricularia*  
 (d) *Nepenthes*, Sweet pea, Cat's nail, *Utricularia*  
 (e) *Utricularia*, *Nepenthes*, Cat's nail, Sweet pea
20. Onion stores food in  
 (a) Underground stem (b) Fleshy scales  
 (c) Root (d) Shoot
21. Study the following statements and select the correct option  
 (A) Buds are present in the axil of leaflets of the compound leaf  
 (B) Pulvinus leaf-base is present in some leguminous plants  
 (C) In *Alstonia*, the petioles expand, become green and synthesize food  
 (D) Opposite phyllotaxy is seen in guava [NCERT; Kerala PMT 2011]  
 (a) (B) and (D) are correct but (A) and (C) are wrong  
 (b) (A) and (C) are correct but (B) and (D) are wrong  
 (c) (A) and (D) are correct but (B) and (C) are wrong  
 (d) (B), (C) and (D) are correct but (A) is wrong  
 (e) (A) and (B) are correct but (C) and (D) are wrong
22. Whorled, simple leaves with reticulate venation are present in [NCERT; Kerala PMT 2010; CBSE PMT (Malina) 2011]  
 (a) China Rose (b) *Alstonia*  
 (c) *Calotropis* (d) Neem
23. Petiole is modified into tendril in [AFMC 1996; Odisha JEE 2000, 10]  
 (a) *Passiflora* (b) *Gloriosa*  
 (c) *Pisum* (d) *Clematis*
24. A unipinnate compound leaf can be differentiated from a branch having simple leaves by  
 (a) Presence of terminal bud in compound leaf  
 (b) Absence of veins in the leaflets  
 (c) Presence of buds in the axils of leaflets  
 (d) Presence of buds in the axils of leaves
25. Cactaceae Stores water in leaves. It implies [Odisha JEE 2008]  
 (a) Ephemerals (b) Drought resistant  
 (c) Annuals (d) Non succulents



26. Ochreate stipules are found in [Odisha JEE 2009]  
 (a) Polygonaceae (b) Acanthaceae  
 (c) Leguminosae (d) Malvaceae

27. Study the following lists

List-I		List-II	
(A)	Entire leaf modified into a spine	(i)	<i>Clematis</i>
(B)	Leaf except stipules modified into a tendril	(ii)	<i>Citrus</i>
(C)	Stipules modified into a tendril	(iii)	<i>Euphorbia</i>
(D)	First leaf of axillary bud modified into a spine	(iv)	<i>Lathyrus</i>
		(v)	<i>Smilax</i>

The correct match is [EAMCET 2009]

A	B	C	D
(a) (iii)	(iv)	(i)	(ii)
(b) (iii)	(i)	(iv)	(ii)
(c) (ii)	(iii)	(i)	(v)
(d) (v)	(ii)	(i)	(iii)

28. 1/3 spiral phyllotaxy (called Tristichous) means [Odisha JEE 2012]

- (a) 3 rows of alternate rows  
 (b) In one circle, there are 3 leaves  
 (c) The angular divergence between 2 leaves is 120°  
 (d) All of these

29. Multicostate parallel type of venation is found in the leaves of [Kerala PMT 2009; Odisha JEE 2011]

- (a) Grasses and palms (b) Banana and canna  
 (c) Castor and china rose (d) Mango and peepal  
 (e) Castor and tapioca

30. In 1/2 distichous phyllotaxy

- (a) 2nd leaf lies on 1st leaf at 180° angle  
 (b) 3rd leaf on 1st leaf at 180° angle  
 (c) 1st leaf lies exactly below 2nd leaf at 120° angle  
 (d) None of these

31. Leaves are situated on [AFMC 2003; CBSE PMT 2005]

- (a) Nodes (b) Internodes  
 (c) Tip (d) None of these

32. The leaves of *Utricularia* plant are modified into [J & K CET 2005]

- (a) Hooks (b) Tendrils  
 (c) Bladders (d) Pitchers

33. The reticulate venation is commonly found in the leaves of [J & K CET 2005]

- (a) Monocot plants (b) Dicot plants  
 (c) Bryophytes (d) Thallophytes

34. Identify in order, the plants showing alternate, opposite and whorled phyllotaxy [NCERT; Kerala PMT 2005]

- (a) China rose, *Calotropis*, *Nerium*  
 (b) China rose, *Nerium*, *Calotropis*  
 (c) *Nerium*, China rose, *Calotropis*  
 (d) *Nerium*, *Calotropis*, China rose  
 (e) *Calotropis*, *Nerium*, China rose

35. The leafless stem of onion which is produced to bear flower is called [AFMC 2006]

- (a) Thalamus (b) Scape  
 (c) Torus (d) Pedicel

36. Leaf of which of the following plant shows circinate venation at young stage [MHCET 2004]

- (a) Fern (b) Mango  
 (c) *Hydrilla* (d) *Funaria*

37. Petiole is winged in

- (a) Citrus (b) Pea leaf  
 (c) *Dionaea* leaf (d) Both (a) and (c)

38. In *Opuntia* the spines are modification of [Pb. PMT 2004; Kerala PMT 2009; AIPMT (Cancelled) 2015]

- (a) Leaf (b) Branch  
 (c) Epidermis (d) Flower

39. Match list I with list II and select the correct option

List I		List II	
A.	Gemmules	1.	<i>Agave</i>
B.	Leaf-buds	2.	<i>Penicillium</i>
C.	Bulbil	3.	Water hyacinth
D.	Offset	4.	Sponges
E.	Conidia	5.	<i>Bryophyllum</i>

[Kerala PMT 2010, 11; CBSE PMT (Mains) 2011]

- (a) A-4, B-5, C-1, D-3, E-2 (b) A-4, B-3, C-2, D-1, E-5  
 (c) A-3, B-5, C-4, D-2, E-1 (d) A-4, B-1, C-5, D-3, E-2  
 (e) A-3, B-5, C-4, D-1, E-2

40. In *Nepenthes* the pitcher is modified

[Kerala CET 2001; Tamil Nadu 2001; Chd. CET 2003]

- (a) Whole leaf (b) Leaf apex  
 (c) Lamina (d) Petiole

41. In 3/8 alternate phyllotaxy (Called ostastichous)

- (a) There are 8 leaves in 3 circles  
 (b) 3 leaves in 8 circles  
 (c) There are 3 rows of leaves  
 (d) There are 8 rows of leaves on three sided stem

42. Name the plant having reticulate venation

[Wardha 2001; Tamil Nadu 2001]

- (a) *Musa* (b) *Mangifera*  
 (c) *Oryza* (d) *Canna*

43. Rachis is present in

- (a) Pinnate compound leaf (b) Palmate compound leaf  
 (c) Both correct (d) Both wrong

44. *Bombax* leaf is [Kerala CET 2000; Tamil Nadu 2001]

- (a) Tripinnate (b) Unipinnate  
 (c) Multifoliate (d) Quadrifoliate  
 (e) Trifoliate

45. Parallel venation occurs in [BVP 2000; Tamil Nadu 2001; Odisha JEE 2005]

- (a) Monocots (b) Dicots  
 (c) All angiosperms (d) Ferns

46. Arrangement of floral leaves in a floral bud is called [Pb. PMT 1997]

(a) Vernation (b) Prefoliation  
(c) Aestivation (d) Ptyxis

47. Phyllode is found in [NCERT; Chd. CET 2003; CBSE PMT (Pre.) 2012]

(a) *Clematis* (b) *Gloriosa*  
(c) *Australian Acacia* (d) *Dischidia*

48. Match the columns

(i) Acicular (1) Grass  
(ii) Linear (2) Nerium  
(iii) Lanceolate (3) Banana  
(iv) Oblong (4) Pine

Options

[AMU (Med.) 2002]

(a) (i) 4 (ii) 1 (iii) 2 (iv) 3 (b) (i) 4 (ii) 1 (iii) 3 (iv) 2  
(c) (i) 4 (ii) 2 (iii) 3 (iv) 1 (d) (i) 4 (ii) 3 (iii) 2 (iv) 1

49. Spiral phyllotaxy in which sixth leaf lies above the first one after completing two circles is [APMEE 2002]

(a) Distichous (b) Tristichous  
(c) Pentastichous (d) Octastichous

50. Ochreate stipules occur in leafy vegetable [APMEE 2002]

(a) *Amaranthus* (b) *Mentha*  
(c) *Platanus* (d) *Rumex*

51. The arrangement and folding of each lamina without any relationship with other leaves in bud, is called [DPMT 1997]

(a) Ptyxis (b) Vernation  
(c) Aestivation (d) Phyllotaxy

52. In spiral phyllotaxy, the number of leaves at each node is

(a) One (b) Two  
(c) Many (d) Three

- 53.



See the following figures and identify leaves A and B

[NCERT]

(a) A – Palmately compound leaf, B – Palmately compound leaf  
(b) A – Pinnately compound leaf, B – Pinnately compound leaf  
(c) A – Palmately compound leaf, B – Pinnately compound leaf  
(d) A – Pinnately compound leaf, B – Palmately compound leaf

54. In Banana, true stem is underground. The stem like structure outside soil is formed by

(a) Peduncle (b) Petiole of leaves  
(c) Leaf bases (d) Overlapping of leaves

55. In *Calotropis* the phyllotaxy is [AMU (Med.) 2009]

(a) Alternate (b) Verticillate  
(c) Opposite and superposed (d) Opposite and decussate

56. Leaf blade is spinous in case of [Manipal 2005]

(a) *Nerium* (b) *Zizipus*  
(c) *Argemone* (d) *Cannabis*

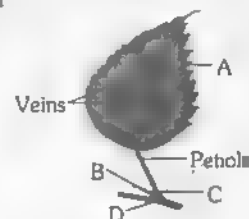
57.  $120^\circ$  phyllotaxy is found in [Odisha JEE 2011]

(a) Tristichous (b) Distichous  
(c) Pentastichous (d) Octastichous

58. How many plants among China rose, *Ocimum*, sunflower, mustard, *Alstonia*, guava, *Calotropis* and *Nerium* (Oleander) have opposite phyllotaxy [NEET (Karnataka) 2013]

(a) Three (b) Four  
(c) Five (d) Two

59. See diagram of a typical leaf. In which of the following option all the four parts marked as A, B, C and D are correctly identified [NCERT]



	A	B	C	D
(a)	Leaflet	Axillary bud	Stipule	Leaf base
(b)	Lamina	Axillary bud	Stipule	Pedicle
(c)	Lamina	Stipule	Axillary bud	Leaf base
(d)	Lamina	Axillary bud	Stipule	Leaf base

### Inflorescence

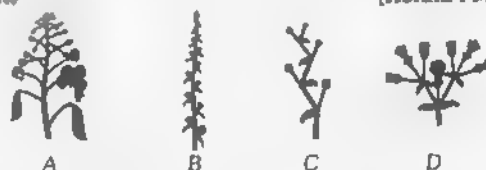
1. Match List I with List II and select the correct option

List I		List II	
A.	Spike	1.	Bougainvillea
B.	Capitulum	2.	Coleus
C.	Dichasial cyme	3.	Adhatoda
D.	Multiparous cyme	4.	Zinnia
E.	Verticillaster	5.	Asclepias

[Kerala PMT 2005, 08]

(a) A – 3, B – 4, C – 1, D – 5, E – 2  
(b) A – 3, B – 1, C – 4, D – 5, E – 2  
(c) A – 2, B – 4, C – 1, D – 5, E – 3  
(d) A – 4, B – 2, C – 5, D – 1, E – 3  
(e) A – 5, B – 4, C – 1, D – 3, E – 2

2. Find out the correct sequence of labelling of diagram given below [Kerala PMT 2006]



(a) A – spike, B – raceme, C – dichasial cyme, D – monochasial cyme  
(b) A – raceme, B – spike, C – monochasial cyme, D – dichasial cyme  
(c) A – dichasial cyme, B – monochasial cyme, C – raceme, D – spike  
(d) A – spike, B – dichasial cyme, C – monochasial cyme, D – raceme  
(e) A – raceme, B – dichasial cyme, C – spike, D – monochasial cyme

3. Select the correct pair of answers in which the former represents the set of characters present in *Poinsettia* and the latter in the pair represents the set of characters present in *Casuarina*

Study the following table

(i)	Modified aerial stem	Unisexual flowers develop acropetally	Chalazal entry of pollen tube
(ii)	Flowers achemydeous	Pedicels of the all flowers are of same length	Presence of false whorl
(iii)	Cohesion of bracts forming a cup	Centrifugal opening of flower	Male flowers many
(iv)	Flower formation on one side in a spiral manner	Presence of rachilla	Terminal part of the peduncle is flowerless

[EAMCET 2009]

- (a) (ii), (iii) (b) (i), (ii)  
(c) (iv), (iii) (d) (iii), (i)

4. In cyathium inflorescence

[Kerala CET 2005; Odisha JEE 2010]

- (a) Single male flower is surrounded by female flowers  
(b) Male and female flowers are borne in different plants  
(c) There is of one male and one female flowers  
(d) Single female flower surrounded by many peripheral male flowers

5. The most advanced type of inflorescence is

- (a) Corymb (b) Catkin  
(c) Spadix (d) Capitulum

6. A student observed 34 inflorescences in *Bougainvillea* and 42 inflorescences in *Poinsettia*. Find out the number of flowers in *Bougainvillea* and the number of female flower in *Poinsettia*, respectively [EAMCET 2009]

- (a) 34, 126 (b) 68, ∞  
(c) 204, 164 (d) 102, 42

7. The flowers in the raceme/racemose are arranged

[Pb. PMT 2000]

- (a) Acropetally (b) Basipetally  
(c) Centripetally (d) Centrifugally

8. Which of the following statements are correct

- (i) When a fruit develops from the inflorescence, it is composite  
(ii) Mesocarp is the edible part in apple  
(iii) Gynobasic style is seen in *Ocimum*  
(iv) Hypanthodium is a special type of inflorescence found in *Euphorbia* species [Kerala PMT 2009]

- (a) (i) and (iv) are correct  
(b) (i) and (iii) are correct  
(c) (i) and (ii) are correct  
(d) (ii), (iii) and (iv) are correct  
(e) (ii) and (iv) are correct

9. Amentum (Catkin) inflorescence is found [JIPMER 1996]

- (a) Mulberry (*Morus*) (b) *Populus* (Poplar)  
(c) *Acalypha* (Cats tail) (d) All of these

10. Characteristic inflorescence of family *Compositae* sunflower is [JIPMER 2000; BHU 2000; CPMT 2004]

- (a) Capitulum (b) Cymose head  
(c) Catkin (d) Spadix

11. Given inflorescence is a [Kerala PMT 2009]

- (a) Cyathium  
(b) Dichasial cyme  
(c) Umbel  
(d) Panicle  
(e) Verticillaster



12. The whorl of bracts present below the inflorescence of *Helianthus* (sunflower) is [Pb. PMT 2000]

- (a) Involucre (b) Involucel  
(c) Stipule (d) Bract

13. Cymose inflorescence is present in

[NCERT; CBSE PMT (Pre.) 2012]

- (a) *Solanum* (b) *Sesbania*  
(c) *Trifolium* (d) *Brassica*

14. Hypanthodium is a specialized type of [BVP 2002]

- (a) Thalamus (b) Ovary  
(c) Fruit (d) Inflorescence

15. Inflorescence in *Musa paradisiaca* (banana) is a

[AMU (Med.) 2002; J & K CET 2010]

- (a) Raceme (b) Catkin  
(c) Spadix (d) Verticillaster

16. The unit of inflorescence in grasses / *gramineae* (*poaceae*) is

[BVP Pune 1998; Odisha JEE 2012]

- (a) Thyrsis (b) Spike  
(c) Spikelet (d) Raceme

17. The capitulum type of inflorescence is found in

[J & K CET 2005]

- (a) Marigold (b) *Salvia*  
(c) *Euphorbia* (d) *Jasmine*

18. In China rose, the inflorescence is [MHCET 2004]

- (a) Cymose (b) Capitulum  
(c) Racemose (d) Solitary cyme

19. Consider the following statements

- (A) In racemose inflorescence the flowers are borne in a basipetal order  
(B) Epigynous flowers are seen in rose plant  
(C) In brinjal the ovary is superior

Of these statements

[Kerala PMT 2010]


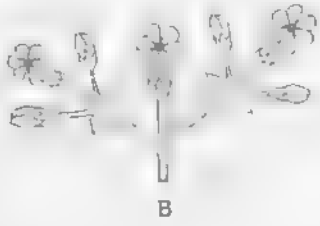
- (a) (A) and (B) are true but (C) is false  
(b) (A) and (C) are true but (B) is false  
(c) (A) and (B) are false but (C) is true  
(d) (A) and (C) are false but (B) is true  
(e) (B) and (C) are true but (A) is false

20. The edible part of cauliflower is [CPMT 2004; AFMC 2005]

- (a) Mesocarp (b) Cotyledons  
(c) Endosperms (d) Inflorescence

21. In 'Tulsi' (*Ocimum*) of *labiatae* the inflorescence is

- (a) Cyathium (b) Verticillaster  
(c) Hypanthodium (d) Raceme of Racemes

22. The inflorescence in cauliflower is [Odisha JEE 2011]  
(a) Compound corymb (b) Corymb  
(c) Umbel (d) Catkin
23. Cyathium is found in genus [KCET 1998, 2000]  
(a) *Croton* (b) *Ficus*  
(c) *Euphorbia* (d) *Ricinus*
24. The special type of inflorescence found in *Ficus* where the female flower are at bottom and male flower near ostiole and enclosed within a cup shaped fleshy thalamus (receptacle) with ostiole is called [Manipal 2000; BHU 2002; Pb. PMT 2004; RPMT 2006]  
(a) Cyathium (b) Verticillaster  
(c) Spadix (d) Hypanthodium
25. An edible inflorescence is  
(a) Corymb (b) Catkin  
(c) Hypanthodium (d) All of these
26. Inflorescence with unisexual sessile flower is [AFMC 1996, 2002; AMU (Med.) 1999]  
(a) Spike (b) Spikelet  
(c) Catkin (d) Spadix
27. Most accurate function in the following statements about inflorescence is [DPMT 1996]  
(a) Dispersal of seeds  
(b) Formation of more fruit  
(c) Formation of pollen grains  
(d) Dispersal of pollens
28. Inflorescence is edible in *Brassica oleracea* [AFMC 1998]  
(a) Var. botrytis (b) Var. capitata  
(c) Var. gongyloides (d) Var. gemifera
29. A beautiful whorl which encloses whole of the inflorescence is [Manipal 2002]  
(a) Bract (b) Spadix  
(c) Spathe (d) Involucre
30. Inflorescence is racemose in [NEET (Karnataka) 2013]  
(a) Brinjal (b) Tulip  
(c) Aloe (d) Soyabean
31. In a cymose inflorescence the main axis [NEET (Karnataka) 2013]  
(a) Has unlimited growth  
(b) Bears a solitary flower  
(c) Has unlimited growth but lateral branches end in flowers  
(d) Terminates in a flower
32. See the following diagrams and identify inflorescence A and B [NCERT]
- 

- (a) A – Cymose, B – Cymose  
(b) A – Racemose, B – Racemose  
(c) A – Racemose, B – Cymose  
(d) A – Cymose, B – Racemose
33. Many plants among *Indigofera*, *Sesbanta*, *Saluta*, *Allium*, *Aloe*, mustard, groundnut, radish, gram and turnip have stamens with different lengths in their flowers [NEET (Phase-II) 2016]  
(a) Six (b) Three  
(c) Four (d) Five

## Flower

1. Flower is intersexual in  
(a) Date palm (b) *Cucurbita*  
(c) *Papaya* (d) *Hibiscus*
2. Thalamus is [NCERT; Bihar PMT 1994]  
(a) Base of flower (b) Base of ovary  
(c) Modification of pollen (d) Modification of petal
3. Synandrous condition is fusion of [Bihar PMT 1994]  
(a) Filaments only  
(b) Both filaments and anthers  
(c) Anthers only  
(d) Petals
4. A characteristic of angiosperms is [HPMT 1994; Rohtak PMT 1994]  
(a) Flower (b) Root  
(c) Seed (d) All of these
5. Which of these is an example for zygomorphic flower with imbricate aestivation [Kerala PMT 2010]  
(a) *Calotropis* (b) Mustard  
(c) *Canna* (d) *Cassia*  
(e) Cucumber
6. Ligulate/strap-shaped corolla occurs in sunflower in [JIPMER 2000]  
(a) Disc florets (b) Immature florets  
(c) Ray florets (d) Both ray and disc florets
7. Beauty of *Bougainvillea* flower is due to [AFMC 1996, 99; BHU 2008]  
(a) Corolla (b) Calyx  
(c) Bracts (d) Androecium
8. Flower is complete when it has  
(a) Calyx, corolla, androecium and gynoecium  
(b) Calyx and corolla  
(c) Androecium and gynoecium  
(d) Corolla, androecium and gynoecium
9. Keel is the characteristic feature of flower of [AIPMT (Cancelled) 2015]  
(a) *Indigofera* (b) *Aloe*  
(c) Tomato (d) Tulip
10. In monoadelphous condition, stamens have  
(a) Filaments of all united in one group but anthers are free  
(b) Filaments united in groups but all anthers are free  
(c) Anthers are fused but filaments are free  
(d) Both anthers and filaments are fused
11. Stamens attached to petals are [BHU 1993]  
(a) Antipetalous (b) Epipetalous  
(c) Epiphyllous (d) Episepalous

12. Flower in which only one set of essential organ is present are said to be [CBSE PMT 2004]
  - (a) Bisexual (b) Monoecious
  - (c) Dioecious (d) Polygamous
  - (e) Unisexual
13. Axis developing between androecium and gynoecium is
  - (a) Anthophore (b) Androphore
  - (c) Gynophore (d) Gynandrophore
14. A plant with both male and female flowers borne over it is [CPMT 1993]
  - (a) Monoecious (b) Dioecious
  - (c) Unisexual (d) Bisexual
15. The expression "gynoecium is apocarpous" implies that the [DUMET 2010]
  - (a) Gynoecium comprises only one pistil which is fused with the stamen
  - (b) Gynoecium comprises more than one carpel, all of which are free
  - (c) Gynoecium comprises only one carpel which is free
  - (d) Gynoecium comprises more than one carpel which are fused
16. When placenta forms a ridge along the ventral suture of the ovary and the ovules are borne on this ridge forming two rows, the placentation is termed as [AMU (Med.) 2009, 12]
  - (a) Axile (b) Parietal
  - (c) Marginal (d) Basal
17. The flower of *Calotropis* has which of the following aestivations [J & K CET 2012]
  - (a) Twisted (b) Imbricate
  - (c) Valvate (d) Vexillary
18. Perigynous flowers are found in [AIPMT (Cancelled) 2015]
  - (a) Cucumber (b) China rose
  - (c) Rose (d) Guava
19. Butterfly shaped flower with one stranded, two wing-like and two keeled petal belong to [AIIMS 2000]
  - (a) Compositae (b) Rubiaceae
  - (c) Malvaceae (d) Papilionaceae
20. On the basis of position of the ovary, mustard plants are [J & K CET 2012]
  - (a) Hypogynous (b) Perigynous
  - (c) Epigynous (d) Zygomorphic
21. In angiospermic bud condition floral bud is covered by whorls of [Odisha JEE 2008]
  - (a) Petal (b) Sepal
  - (c) Anther (d) Stigma
22. The most suitable flower for study of floral parts is
  - (a) Rose (b) Sunflower
  - (c) Mustard (d) Cucumber
23. In Maize, the flowers are [CPMT 1994]
  - (a) Absent
  - (b) Unisexual but on different plants
  - (c) Bisexual
  - (d) Unisexual but on the same plant
24. Odd sepal is enlarged and leaf-like in
  - (a) Rose (b) *Smilax*
  - (c) *Mussaenda* (d) *Bougainvillea*
25. Sometimes sepals are modified into hairy structures which are useful in dispersal of seeds. These are called
  - (a) Tepals (b) Epik
  - (c) Pappus (d) Trichome
26. Glumes are modified [CPMT 2009; MP PMT 2013]
  - (a) Petals
  - (b) Bracts (Dry and scaly bracts)
  - (c) Gynoecium
  - (d) Androecium
27. Pappus is modification of [Chd. CET 1997; BHU 2005]
  - (a) Bracts (b) Bracteoles
  - (c) Corolla (d) Calyx
28. Cruciform corolla is found in
  - (a) Pea (b) China Rose
  - (c) Radish (d) Sunflower
29. In which type of aestivation the petal arrangement is 2 external, 2 internal and 1 partly external and partly internal seen [Odisha JEE 2010]
  - (a) Twisted (b) Imbricate
  - (c) Quincuncial (d) Valvate
30. Two minute scales or lodicules occur in [AIIMS 1997; Chd. CET 1997]
  - (a) *Citrus medica* (b) *Triticum aestivum*
  - (c) *Helianthus annuus* (d) *Gossypium herbaceum*
31. Among china rose, mustard, Brinjal, potato, guava, cucumber onion and tulip, how many plants have superior ovary [AIPMT 2015]
  - (a) Six (b) Three
  - (c) Four (d) Five
32. How many plants in the list given below have marginal placentation : Mustard, Gram, Tulip, Asparagus, Arhar, Sun hemp, Chilli, Colchicine, Onion, Moong, Pea, Tobacco, Lupin [NCERT; CBSE PMT (Malna) 2012]
  - (a) Four (b) Five
  - (c) Six (d) Three
33. In china rose the flowers are [AIIMS 1999; NEET 2013]
  - (a) Zygomorphic, epigynous with twisted aestivation
  - (b) Actinomorphic, hypogynous with twisted aestivation
  - (c) Actinomorphic, epigynous with valvate aestivation
  - (d) Zygomorphic, hypogynous with imbricate aestivation
34. Versatile anther is attached to filament [BHU 1996]
  - (a) At top firmly
  - (b) At base firmly
  - (c) Throughout length
  - (d) About middle of connective allowing free movement
35. Choose the product that is derived from style and stigma [CBSE PMT 1992]
  - (a) Saffron (b) *Fenugreek*
  - (c) *Asafoetida* (d) *Psyllium*
36. Ray florets of sunflower (Compositae) are
  - (a) Bisexual (b) Unisexual
  - (c) Asexual (d) None of these

37. Part of pistil which receives pollen is

[NCERT; MP PMT 2004]

- (a) Ovary (b) Style  
(c) Stigma (d) Ovule

38. An example of axile placentation is

[CBSE PMT 2009; AIPMT 2015]

- (a) Argemone (b) Dianthus  
(c) Lemon (d) Marigold

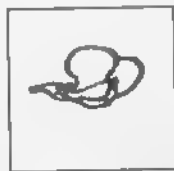
39. The perianth is the term used when

- (a) Androecium and gynoecium are similar  
(b) Androecium and calyx are similar  
(c) Corolla and gynoecium are similar  
(d) Calyx and corolla are similar

40. The correct sequence of types of corolla in the following figures is [Kerala PMT 2008]



(A)



(B)



(C)



(D)



(E)

- (a) A – Caryophyllaceous, B – papilionaceous, C – bilabiate, D – tubular, E – bell-shaped  
(b) A – papilionaceous, B – bilabiate, C – tubular, D – bell-shaped, E – caryophyllaceous  
(c) A – bilabiate, B – papilionaceous, C – caryophyllaceous, D – bell-shaped, E – tubular  
(d) A – caryophyllaceous, B – bilabiate, C – papilionaceous, D – tubular, E – bell-shaped  
(e) A – tubular, B – bell-shaped, C – caryophyllaceous, D – bilabiate, E – papilionaceous

41. A flower is zygomorphic when [WB JEE 2011]

- (a) Any transverse section divides it into two equal halves  
(b) Only one transverse section divides it into two equal halves  
(c) Every vertical section passing through its centre divides it into two equal halves  
(d) Only one vertical section passing through its centre divides it into two equal halves

42. Flower is a modified shoot as

- (a) Thalamus may elongate to show internodes  
(b) There is aggregation into inflorescence  
(c) It bears essential organs  
(d) It may have epicalyx

43. Usually, the whorl in a flower that attracts insects and protects the essential parts is [KCET 2012]

- (a) Calyx (b) Androecium  
(c) Gynoecium (d) Corolla

44. When margin of thalamus grows upward enclosing ovary completely and getting fused with it and the other parts of flower arise above the ovary, the flower is said to be

[AMU (Med.) 2012]

- (a) Hypogynous (b) Perigynous  
(c) Epigynous (d) Inferior

45. Smallest flower belongs to

[DPMT 2004; CPMT 2009]

- (a) *Rosa indica* (b) *Wolffia microscopica*  
(c) *Ranunculus scleratus* (d) *Colocasia antiquorum*

46. Largest flower is that of

[CPMT 1996; BHU 2005; Odisha JEE 2005]

- (a) Sunflower (b) *Rafflesia*  
(c) *Nelumbo* (d) *Drosera*

47. Polyadelphous anthers are present in

- (a) Sunflower (b) Lemon  
(c) Lady's finger (d) Peanut

48. Flowers of Liliaceae, Malvaceae and Solanaceae are

[RPMT 1994, 96; BHU 1995]

- (a) Hypogynous (b) Perigynous  
(c) Epigynous (d) Amphigynous

49. Flowers and stamens of compositae are

- (a) Hypogynous and inferior  
(b) Epigynous and superior  
(c) Hypogynous and superior  
(d) Epigynous and inferior

50. Compound apocarpous gynoecium is found in

[CBSE PMT 1991]

- (a) Lily (b) Hollyhock  
(c) Lotus/*Ranunculus* (d) Pumpkin

51. The primitive type of stamens are found in the flowers family [AIIMS 1994]

- (a) Liliaceae  
(b) Malvaceae  
(c) Gramineae/Poaceae  
(d) Degeneriaceae/Magnoliaceae

52. Find out the pairs, which are correctly, matched with respect to aestivation of petals

- I. Valvate – Calotropis II. Twisted – Bean  
III. Imbricate – Cassia IV. Vexillary – China rose

[Kerala PMT 2012]

- (a) II and IV (b) I and II  
(c) I and III (d) III and IV  
(e) II and III

53. Oblique septum and swollen placenta is characteristic feature of

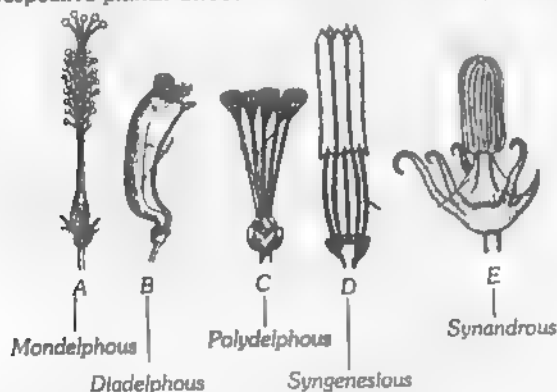
- (a) *Gloriosa superba* (b) *Capsicum frutescens*  
(c) *Althea rosea* (d) *Dalbergia sissoo*

54. Ascending imbricate corolla is found in

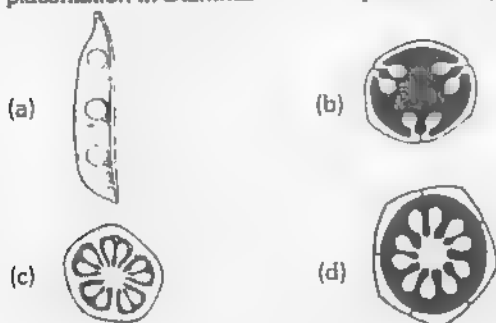
- (a) *Pisum/Papilionatae*  
(b) *Tamarindus/Caesalpinioideae*  
(c) *Mimosa/Mimosoidae*  
(d) *Datura/Solanaceae*

55. A perennial shrub has compound leaves and solitary zygomorphic and epigynous flowers. Each flower reveals dichlamydeous condition with many stamens and multiple fruits with exalbuminous seeds. What is the ratio of advanced and primitive characters in it [EAMCET 2009]  
(a) 1 : 2 (b) 2 : 3  
(c) 1 : 1 (d) 3 : 2
56. Parachute like pappus is found in [JKCME 2000]  
(a) Liliaceae/Cotton (b) Gramineae/Paddy  
(c) Compositae/Marigold (d) Solanaceae/Calotropis
57. In *Gossypium* the type of cohesion is [RPMT 1992, 96]  
(a) Monoadelphous (b) Diadelphous  
(c) Polyadelphous (d) Monotheous
58. A plant with actinomorphic and hypogynous flowers, heterochlamydeous perianth, dorsifixed and extrorse anthers dehiscing transversely belongs to [EAMCET 2009]  
(a) Coronariae (b) Bicarpellatae  
(c) Thalamiflorae (d) Calyciflorae
59. A plant has an androecium with monadelphous stamens, monotheous and reniform anthers. The corolla exhibits contorted aestivation. The Plant could be [BHU 1995; KCET 2009]  
(a) *Rauwolfia* (b) *Vinca*  
(c) *Nerium* (d) *Hibiscus*
60. In guava, cucurbits flowers are [WB JEE 2008]  
(a) Hypogynous flower  
(b) Epigynous flower  
(c) Perigynous flower  
(d) Both hypogynous & perigynous
61. Gynandrous condition means [Odisha JEE 2010]  
(a) Adhesion of stamens and carpels  
(b) Cohesion of stamens  
(c) Stamens united by filaments only  
(d) Free stamens
62. In floral formula (K) denotes [NCERT; WB JEE 2008]  
(a) Polysepalous (b) Gamosepalous  
(c) Polypetalous (d) Gamopetalous
63. To Which of the following flower 'synandrous' condition is found [WB JEE 2008]  
(a) Sunflower (*Helianthus* sp) (b) Gourd (*Cucurbita* sp)  
(c) Pea (*Pisum sativum*) (d) Lemon (*Citrus* sp)
64. A monocarpic plant is one which [MP PMT 2009; Odisha JEE 2009]  
(a) Has only one carpel  
(b) Flowers once in a life-time  
(c) Produces only one seed  
(d) Produces only one fruit
65. The term Anthesis is used for [AIEEE Pharmacy 2004; AFMC 2012]  
(a) Cluster of anthers (b) Opening of flowers  
(c) Dehiscence of anthers (d) Falling of flowers
66. Plants having flowers with free petals are placed under [VITEEE 2006]  
(a) Polypetalae (b) Monocotyledons  
(c) Gamopetalae (d) Monochlamydae
67. When the other floral parts are arranged at the base of the gynoecium, the flower is called [WB JEE 2009]  
(a) Hypogynous flower (b) Perigynous flower  
(c) Epigynous flower (d) Agynous flower
68. Zygomorphic condition can be represented as [NCERT; CPMT 2009]  
(a)  $\oplus$  (b)  $\%$   
(c) P (d) G
69. Gynoecium with fused carpels [AFMC 2008]  
(a) Syncarpous (b) Apocarpous  
(c) Syngenecium (d) None of these
70. Which of the following is regarded as equivalent to perianth [AIIMS 1996]  
(a) Glume (b) Lodicule  
(c) Superior palea (d) Inferior palea
71. When the anthers mature earlier than the stigma of ones own flower, the condition is known as  
(a) Herkogamy (b) Protandry  
(c) Heterostyly (d) Heterogamy
72.  $A_{1+(9)}$  stands for  
(a) Adelphous (b) Synantherous  
(c) Diadelphous (d) None of these
73. Obdiplostemonous condition is that in which the stamens are in two whorls and  
(a) Outer whorl is fused to inner whorl  
(b) Outer whorl is opposite to petals  
(c) Inner whorl is opposite to petals  
(d) Both inner as well as outer whorls are opposite to petals
74. Choose the specific characters of the flowers of *Canna* [Kerala PMT 2012]  
(a) Actinomorphic and radial symmetry  
(b) Irregular and bilateral symmetry  
(c) Irregular and zygomorphic  
(d) Irregular and radial symmetry  
(e) Irregular and asymmetric
75. Plants with single whorl of perianth are placed under [Kerala PMT 2007]  
(a) Class : Monocot Sub class : Monochlamydeae  
(b) Class : Dicot Series : Monochlamydeae  
(c) Class : Dicot Sub class : Monochlamydeae  
(d) Class : Monocot Sub class : Gamopetalae  
(e) Class : Dicot Series : Bicarpellatae
76. In some plants the style is shorter. But in some others, it is longer than the stamens. This condition is called [MHCET 2003]  
(a) Homogamy (b) Homostyly  
(c) Heterostyly (d) None of these
77. Which of the following flowers show heterostyle [MHCET 2002, 06]  
(a) *Mirabilis* (b) *Hibiscus*  
(c) *Primrose* (d) *Pisum*
78. The example for trimerous, unisexual flower is [KCET 2004]  
(a) *Cocos nucifera* (b) *Hibiscus*  
(c) *Tamarind* (d) *Pea*

79. In many cultivated ornamental flowers, number of petal whorls is higher than the one in wild type. Extra petals are generally modified [JKCME 2000]  
(a) Sepals (b) Petals  
(c) Stamens (d) Pistils
80. The corolla of *Hibiscus* is [MHCET 2002]  
(a) Gamopetalous, valvate (b) Gamopetalous, twisted  
(c) Polypetalous, valvate (d) Polypetalous, twisted
81. Arrangement of sepals and petals in the bud condition is called [MHCET 2004, 05]  
(a) Ptyxis (b) Placentation  
(c) Aestivation (d) Phyllolaxy
82. Corolla in China rose are [MHCET 2004]  
(a) 5, gamopetalous, twisted (b) 5, gamopetalous valvate  
(c) 5, polypetalous valvate (d) 5, polypetalous contorted
83. Keel is characteristic of the flower of [CBSE PMT (Pre.) 2010]  
(a) Bean (b) Gulmohur  
(c) Cassia (d) Calotropis
84. In unilocular ovary with a single ovule the placentation is [NCERT; CBSE PMT (Pre.) 2010]  
(a) Axile (b) Marginal  
(c) Basal (d) Free Central
85. The following diagrams A, B, C, D and E show the different types of arrangement of stamens based on the cohesion of their parts in different plants. Assign the stamens to their respective plants. Choose the correct answer [KCET 2010]



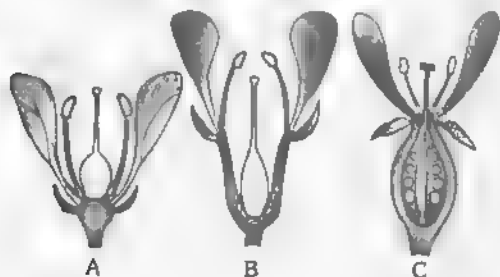
- | A                                 | B                        | C                        | D                        | E                        |
|-----------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| (a) <i>Hibiscus rosa-sinensis</i> | <i>Helianthus annuus</i> | <i>Cucurbita pepo</i>    | <i>Crotalaria juncea</i> | <i>Bombax ceiba</i>      |
| (b) <i>Hibiscus rosa-sinensis</i> | <i>Bombax ceiba</i>      | <i>Cucurbita pepo</i>    | <i>Crotalaria juncea</i> | <i>Helianthus annuus</i> |
| (c) <i>Hibiscus rosa-sinensis</i> | <i>Bombax ceiba</i>      | <i>Helianthus annuus</i> | <i>Cucurbita pepo</i>    | <i>Crotalaria juncea</i> |
| (d) <i>Hibiscus rosa-sinensis</i> | <i>Crotalaria juncea</i> | <i>Bombax ceiba</i>      | <i>Helianthus annuus</i> | <i>Cucurbita pepo</i>    |
86. Which one of the following diagrams represents the placentation in *Dianthus* [CBSE PMT (Mains) 2011]



87. Flowers are Zygomorphic in [NCERT; CBSE PMT (Pre.) 2011]  
(a) *Datura* (b) Mustard  
(c) Gulmohur (d) Tomato
88. Which one of the following statements is correct [NCERT; CBSE PMT (Pre.) 2011]  
(a) Flower of tulip is a modified shoot  
(b) In tomato, fruit is a capsule  
(c) Seeds of orchids have oil-rich endosperms  
(d) Placentation in primrose is basal
89. Which of the following plants has the floral characters like zygomorphic flower, vexillary aestivation, diadelphous androecium and marginal placentation [Kerala PMT 2011]  
(a) *Pisum* (b) *Belladonna*  
(c) Brinjal (d) *Asparagus*  
(e) *Aloe*
90. Flowers are unisexual in [AIPMT 2015]  
(a) Cucumber (b) China rose  
(c) Onion (d) Pea
91. Thalamus of hypogynous ovary is [Odisha JEE 2011]  
(a) Convex  
(b) Concave  
(c) Flat with partly cup shaped  
(d) None of these
92. The type of placentation in which ovary is syncarpous unilocular and ovules on sutures is called [CPMT 2010]  
(a) Marginal placentation (b) Apical placentation  
(c) Parietal placentation (d) Superficial placentation
93. The ovary is half inferior in flowers of [NCERT; CBSE PMT (Pre.) 2010, 11]  
(a) Guava (b) Peach/Plum  
(c) Cucumber (d) Cotton
94. The gynoecium consists of many free pistils in flowers of [CBSE PMT (Pre.) 2012]  
(a) *Aloe* (b) Tomato  
(c) Papaver (d) *Michelia*
95. The condition in which stamens are fused by anthers only, whereas the filaments remain free, is termed as [Odisha JEE 2012]  
(a) Adelphous (b) Syngenesious  
(c) Synandrous (d) Polyandrous
96. Among bitter gourd, mustard, brinjal, pumpkin, chinrose, lupin, cucumber, sunnhemp, gram, guava, bean, chilli, plum, petunia, tomato, rose, withania, potato, onion, aloe and tulip how many plants have hypogynous flower [NEET 2013]  
(a) Eighteen (b) Six  
(c) Ten (d) Fifteen
97. Among flowers of *Calotropis*, tulip, *Sesbania*, *Asparagus*, Colchicine, Sweet pea, *Petunia*, *Indigofera*, Mustard, Soyabean, Tobacco and groundnut how many plants have corolla with valvate aestivation [NEET (Karnataka) 2013]  
(a) Six (b) Seven  
(c) Eight (d) Five



98. Match the following figures with I, II and III  
 (I) Hypogynous flower (II) Perigynous flower  
 (III) Epigynous flower



[NCERT]

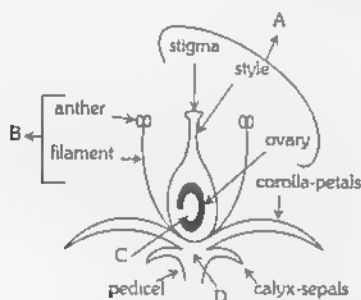
- (a) A – III, B – I, C – II (b) A – III, B – II, C – I  
 (c) A – I, B – III, C – II (d) A – I, B – II, C – III

99. Match the Column I with Column II and Column III

Column I	Column II	Column III
A. Marginal	I.	1. Sunflower, Marigold
B. Axile	II.	2. Dianthus, Primrose
C. Parietal	III.	3. Mustard, Argemone
D. Free Central	IV.	4. China rose, Tomato, Lemon
E. Basal	V.	5. Pea

[NCERT; Kerala PMT 2010, 11; NEET (Phase-II) 2016]

- (a) A – V, 1; B – III, 2; C – II, 4; D – I, 5; E – IV, 3  
 (b) A – V, 1; B – II, 4; C – I, 2; D – III, 3; E – IV, 5  
 (c) A – I, 5; B – II, 4; C – III, 3; D – IV, 2; E – V, 1  
 (d) A – V, 5; B – II, 4; C – I, 3; D – III, 2; E – IV, 1
100. See figure of a typical flower. In which one of the options all the four parts A, B, C and D are correctly identified [NCERT]



	A	B	C	D
(a)	Gynoecium	Stamen	Ovule	Thalamus
(b)	Microsporophyll	Stamen	Ovule	Thalamus
(c)	Gynoecium	Stamen	Seed	Thalamus
(d)	Gynoecium	Megasporophyll	Ovule	Thalamus

101. When the margins of sepals or petals overlap one another without any particular direction, the condition is termed as [CBSE PMT 2014]

- (a) Twisted (b) Valvate  
 (c) Vexillary (d) Imbricate

102. The standard petal of a papilionaceous corolla is also called [NEET (Phase-I) 2016]

- (a) Carina (b) Pappus  
 (c) Vexillum (d) Corona

103. Proximal end of the filament of stamen is attached to the [NEET (Phase-I) 2016]

- (a) Anther (b) Connective  
 (c) Placenta (d) Thalamus or petal

104. The term 'polyadelphous' is related to [NEET (Phase-II) 2016]

- (a) Calyx (b) Gynoecium  
 (c) Androecium (d) Corolla

105. Radial symmetry is found in the flowers of [NEET (Phase-II) 2016]

- (a) Cassia (b) Brassica  
 (c) Trifolium (d) Pisum

### Seeds and Fruits

1. Seeds of the orchids are  
 (a) Large and heavy (b) Light and dry  
 (c) Minute and sticky (d) None of these
2. Single flower with multiple ovaries is called [Odisha JEE 2008]  
 (a) Composite fruit (b) Simple fruit  
 (c) Aggregate fruit (d) None of these
3. The megasporangium of the angiosperms on maturation gives rise to  
 (a) A fruit (b) Seed  
 (c) An embryo (d) Cotyledons
4. After fertilization, the seed coats of seed develop from [RPMT 2002]  
 (a) Integuments (b) Embryo sac  
 (c) Chalaza (d) Ovule
5. Cereals during germination derive their food from [Odisha JEE 2008]  
 (a) Starch (b) Soil  
 (c) Aleurone grains (d) Embryo
6. Karyopsis is [VITEEE 2008]  
 (a) One seeded fruit (b) Two seeded fruit  
 (c) Three seeded fruit (d) Four seeded fruit
7. Cotyledons and testa respectively are edible parts in [CBSE PMT 2009]  
 (a) Groundnut and pomegranate  
 (b) Walnut and tamarind  
 (c) French bean and cocount  
 (d) Cashew nut and litchi
8. Plants with inferior ovary usually bear [AIIMS 2012]  
 (a) Pseudocarps (b) Berries  
 (c) Aggregate fruits (d) Seedless fruits

9. The plant whose seeds are known to have longest viability period is [AIIMS 1993]  
(a) *Nelumbo nucifera* (lotus) (b) *Triticum vulgare* (wheat)  
(c) *Zizyphus jujuba* (ber) (d) *Carica papaya* (papaya)
10. Which one of the following is a non-endospermic seed [MHCET 2015]  
(a) Sunflower (b) Coconut  
(c) Ground nut (d) Wheat
11. "Embryo are not differentiated into different tissues at the time of fruit ripening". Select option related to this statement [GUJCET 2014]  
(a) Exogenous dormancy, physiological dormancy  
(b) Endogenous dormancy, morphological dormancy  
(c) Exogenous dormancy, morphological dormancy  
(d) Endogenous dormancy, mechanical dormancy
12. Seed develop from [CBSE PMT 1993; MP PMT 2010, 12]  
(a) Ovules (b) Ovaries  
(c) Anthers (d) Pistils
13. In non-endospermic seeds, food is stored in [CPMT 1996]  
(a) Seed coat (b) Endosperm  
(c) Cotyledons (d) Ovule
14. Vivipary means [RPMT 1995]  
(a) Fruits are not formed  
(b) Germination of seed on mother plant  
(c) Formation of fruits directly by embryo  
(d) Production of fruitless plant
15. In which of the following the seed germinates and still attached with the main plant [AFMC 1995]  
(a) Mango (b) *Rhizophora*  
(c) Neem (d) Coconut
16. Edible part of mango is [NCERT; BVP 2002; CBSE PMT 2004; AFMC 2010]  
(a) Epicarp (b) Mesocarp  
(c) Endocarp (d) Receptacle
17. Placenta and pericarp are both edible portions in [BCECE 2005; KCET 2007; CBSE PMT 2014]  
(a) Tomato (b) Potato  
(c) Apple (d) Banana
18. In caryopsis type of fruit [MHCET 2004; J & K CET 2008]  
(a) Seed is absent  
(b) Three layers of pericarp are distinct  
(c) Seed coat and pericarp are fused  
(d) Autochory occurs
19. Aggregate fruit develops from [MHCET 2003; Odisha JEE 2011; CBSE PMT 2014]  
(a) Multicarpellary, apocarpous ovary  
(b) Multicarpellary ovary  
(c) Multicarpellary, syncarpous ovary  
(d) Monocarpellary ovary
20. Which of the following is a wheat fruit [BHU 2004; AFMC 2009]  
(a) Achene (b) Cypsella  
(c) Caryopsis (d) Endosperm
21. A fleshy-fruit with leathery exocarp is called [Odisha JEE 2004]  
(a) Drupe (b) Berry  
(c) Pome (d) Hesperidium
22. .... type of fruit is present in rice [Odisha JEE 2004; BHU 2008]  
(a) Cypsela (b) Capsule  
(c) Caryopsis (d) Cremocarp
23. One of the following is a dry indehiscent fruit [CBSE PMT 2004]  
(a) Caryopsis (b) Pod  
(c) Follicle (d) Lomentum  
(e) Capsule
24. The ground nut seeds are [MHCET 2000]  
(a) Geocarpic (b) Photocarpic  
(c) Amphicarpic (d) Hydrocarpic
25. Lomentum is a kind of [Pb. PMT 2004]  
(a) Inflorescence (b) Plant  
(c) Fruit (d) Insect
26. A fruit developed from hypanthodium inflorescence is called [CBSE PMT 2009]  
(a) Hesperidium (b) Sorosis  
(c) Syconus (d) Caryopsis
27. Maize grain is [NCERT; AFMC 2005]  
(a) Seed (b) Embryo  
(c) Ovule (d) Fruit
28. The fruit in *Datura* is [MHCET 2000]  
(a) Loculicidal capsule (b) Septifragal capsule  
(c) Septicidal capsule (d) Porous capsule
29. All structures within the seed coat are called [MHCET 2002]  
(a) Endosperm (b) Cotyledon  
(c) Embryo (d) Kernel
30. To remove seed dormancy by mechanically removing the seed coat, is called [BVP 2004; AFMC 2004]  
(a) Stratification (b) Scarification  
(c) Vernalization (d) Photoperiodism
31. An example of a seed with endosperm perisperm and caruncle is [CBSE PMT 2009]  

Or

Which one of the following is an endospermic seed [Kerala CET 2002]  

Or

In which of the following plants, cotyledons form the first pair of leaves [AIIMS 1992]  
(a) Cotton (b) Coffee  
(c) Lily (d) Castor
32. Pepo fruit is found in [JIPMER 1997]  
(a) Cruciferae (b) Cucurbitaceae  
(c) Liliaceae (d) Solanaceae
33. The fruit is chambered, developed from inferior ovary and has seeds with succulent testa in [CBSE PMT 2008]  
(a) Guava (b) Cucumber  
(c) Pomegranate (d) Orange
34. Essential requirement for seed germination [CPMT 2005]  
(a)  $H_2O$  and  $O_2$   
(b)  $O_2$  and light  
(c)  $H_2O$  and high temperature  
(d) Scarification and vernalisation
35. In orange which part is edible [BHU 2012]  
(a) Mesocarp (b) Endocarp  
(c) Aril (d) Placental hairs

36. The fruit developed from the single ovary is said to be  
[J & K CET 2005; KCET 2012]

(a) Composite type (b) Simple type  
(c) Aggregate type (d) None of these

37. The fleshy fruits with hard and stony endocarp are called  
[J & K CET 2005; KCET 2009]

(a) Drupe (b) Berry  
(c) Pepo (d) Pome

38. The edible dry fruit 'chilgoza' is [BHU 2005]

(a) Fruit of *Cycas* (b) Fruit of *Pinus gerardiana*  
(c) Seed of *Cycas* (d) Seed of *Pinus gerardiana*

39. Edible part in 'sorosis' a composite fruit is [BHU 2005]

(a) Cotyledons (b) Endosperm  
(c) Perianth and peduncle (d) Fleshy thalamus

40. Fruit of grape vine is [Odisha JEE 2012]

(a) Siliqua (b) Lomentum  
(c) Berry (d) Drupe

41. The given figure represents anacardium (cashewnut). Which is the correct statement [Manipal 2005]

(a) The upper part is a false fruit  
(b) The upper part is a true fruit  
(c) The lower part is a seed  
(d) There is no fruit at all



42. Edible part of Apple is  
[Odisha JEE 2005; AMU (Med.) 2006; J & K CET 2012]

(a) Mesocarp (b) Calyx  
(c) Thalamus (d) Pericarp

43. The hardest part of drupe is [Manipal 2005]

(a) Mesocarp (b) Endocarp  
(c) Pericarp (d) Epicarp

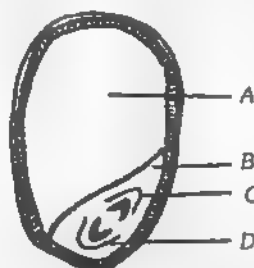
44. Which of the following correctly represents the type of fruits given  
[Kerala PMT 2000]



- (a) 1. Berry ; 2. Caryopsis ; 3. Drupe ; 4. Sorosis ; 5. Aggregate  
(b) 2. Berry ; 3. Caryopsis ; 4. Drupe ; 1. Sorosis ; 5. Aggregate  
(c) 2. Berry ; 3. Caryopsis ; 4. Drupe ; 5. Legume ; 1. Aggregate  
(d) 1. Beccate ; 3. Caryopsis ; 4. Drupe ; 1. Sorosis ; 5. Composite  
(e) 2. Berry ; 3. Caryopsis ; 4. Drupe ; 1. Sorosis ; 5. Legume

45. The diagram represents the L. S of monocot seed. Choose the correct combination of labelling

[Kerala PMT 2006; KCET 2009]



- (a) (A) Aleurone layer (B) Scutellum (C) Coleoptile (D) Coleorhiza  
(b) (A) Seed coat (B) Scutellum (C) Coleoptile (D) Coleorhiza  
(c) (A) Epithelium (B) Scutellum (C) Coleoptile (D) Coleorhiza  
(d) (A) Endosperm (B) Scutellum (C) Coleoptile (D) Coleorhiza  
(e) (A) Endosperm (B) Scutellum (C) Plumule (D) Radicle

46. Match the items in column I with column II and choose the correct answer

Column I		Column II	
A.	Apple	1.	Outer portion of receptacle
B.	Coconut	2.	Fleshy thalamus
C.	Jack fruit	3.	Thalamus & pericarp
D.	Guava	4.	Endosperm
E.	Pineapple	5.	Bract, perianth & seeds

[Kerala PMT 2006]

- (a) A-2, B-3, C-4, D-5, E-1  
(b) A-5, B-3, C-1, D-4, E-2  
(c) A-2, B-3, C-1, D-5, E-4  
(d) A-2, B-4, C-5, D-3, E-1  
(e) A-5, B-4, C-3, D-2, E-1

47. How many plants in the list given below have composite fruits that develop from an inflorescence. Walnut, poppy, radish, fig, pineapple, apple, tomato, mulberry

[NCERT; CBSE PMT (Pre.) 2012]

- (a) Four (b) Five  
(c) Two (d) Three

48. A fruit developed from a condensed inflorescence is [AIIMS 2010]

(a) Simple fruit (b) Aggregate fruit  
(c) Composite fruit (d) Etaerio

49. Pineapple (ananas) fruit develops from [CBSE PMT 2006; DUMET 2009]

(a) A cluster of compactly borne flowers on a common axis  
(b) A multilocular monocarpellary flower  
(c) A unilocular polycarpellary flower  
(d) A multipistillate syncarpous flower

50. In which of following fruits is the edible part the aril [CBSE PMT 1999, 2005, 06; Wardha 2005; AFMC 2009]

(a) Orange (b) Litchi  
(c) Custard apple (d) Pomegranate

51. An enzyme that can stimulate germination of barley seeds is [CBSE PMT 2006]

(a) Protease (b) Invertase  
(c)  $\alpha$ -amylase (d) Lipase

52. Hesperidium of orange is a modification of [DPMT 2006]

(a) Berry (b) Drupe  
(c) Pome (d) Aggregate fruit

53. In a cereal grain the single cotyledon of embryo is represented by [NCERT; CBSE PMT 2006]

(a) Prophyll (b) Coleoptile  
(c) Coleorhiza (d) Scutellum

54. Match Column - I with Column - II and choose the correct answers

Column - I		Column - II	
A.	Coleorhiza	1.	Grapes
B.	Food storing tissue	2.	Mango
C.	Parthenocarpic fruit	3.	Maize
D.	Single seeded fruit developing from monocarpellary superior ovary	4.	Radicle
E.	Membranous seed coat	5.	Endosperm

[NCERT; Kerala PMT 2007]

- (a) A-3, B-1, C-4, D-2, E-5  
(b) A-4, B-2, C-5, D-1, E-3  
(c) A-5, B-1, C-3, D-4, E-2  
(d) A-1, B-3, C-2, D-5, E-4  
(e) A-4, B-5, C-1, D-2, E-3

55. Dry indehiscent single-seeded fruit formed from bicarpellary syncarpous inferior ovary is [CBSE PMT 2008]

(a) Berry (b) Cremocarp  
(c) Caryopsis (d) Cypsela

56. The fleshy receptacle of syconus of fig encloses a number of [CBSE PMT 2008]

(a) Berries (b) Mericarps  
(c) Achenes (d) Samaras

57. In which plant the fruit is a drupe, seed coat is thin, embryo is inconspicuous and endosperm is edible [NCERT;

DUMET 2009; CPMT 2010; NEET 2017]

(a) Groundnut (b) Wheat  
(c) Apple (d) Coconut

58. Which one of the following is a true nut [BHU 2008]

(a) Walnut (b) Groundnut  
(c) Cashewnut (d) Coconut

59. In drupe of coconut the mesocarp is [NCERT; AMU (Med.) 2009, 12]

(a) Fleshy (b) Fibrous  
(c) Stony (d) Watery

60. An example of false fruit is [CPMT 2009; AFMC 2010]

(a) Apple (b) Banana  
(c) Grapes (d) Mango

61. Bracts, perianth and seeds are edible parts of [MP PMT 2010]

(a) *Cocos nucifera*  
(b) *Artocarpus heterophyllus*  
(c) *Magnifera indica*  
(d) *Argemone mexicana*

62. Which one of the following statements is correct [NCERT; CBSE PMT 2014]

(a) A proteinaceous aleurone layer is present in maize grain  
(b) A sterile pistil is called a staminode  
(c) The seed in grasses is not endospermic  
(d) Mango is a parthenocarpic fruit

63. Non endospermic seeds are found in [Odisha JEE 2010]

(a) Wheat (b) Castor  
(c) Barley (d) Bean

64. The scutellum observed in a grain of wheat or maize is comparable to which part of the seed in other monocotyledons [CBSE PMT (Pre.) 2010]

(a) Plumule (b) Cotyledon  
(c) Endosperm (d) Aleurone layer

65. A drupe develops in [CBSE PMT (Pre.) 2011]

(a) Tomato (b) Mango  
(c) Wheat (d) Pea

66. Read the following statements A and B

(A) Many organs of aquatic plants float in water  
(B) Large air gaps are present in the collenchyma tissues of lotus leaf

Select the correct answer

[KCET 2011]

- (a) Statement A is correct and B is wrong  
(b) Statement B is correct and A is wrong  
(c) Statements A and B both are correct  
(d) Statements A and B both are wrong

67. Match the types of fruits listed in Column I with the examples listed in Column II. Choose the answer which gives the correct combination of the two columns

Column I		Column II	
A.	Capsule	1.	Paddy
B.	Berry	2.	Mango
C.	Drupe	3.	Sunflower
D.	Cypsela	4.	Tomato
		5.	Lady's finger

[KCET 2011]

- (a) A-5, B-4, C-2, D-3 (b) A-5, B-3, C-1, D-2  
(c) A-4, B-5, C-2, D-3 (d) A-1, B-2, C-3, D-5

68. In which of the following types the fruit is multilocular and split open longitudinally along dorsal sutures [Odisha JEE 2010]

(a) Capsular (b) Loculicidal  
(c) Septicidal (d) Septifragal

69. Seed coat is not thin, membranous in [NEET 2013]

(a) Gram (b) Maize  
(c) Coconut (d) Groundnut

70. Albuminous seeds store their reserve food mainly in [NEET (Karnataka) 2013]

(a) Endosperm (b) Cotyledons  
(c) Hypocotyl (d) Perisperm

71. Figure - I - Mango, Figure - II - Coconut are shown in the following diagram. Identify the parts of the fruit A, B, C and D are respectively [NCERT]

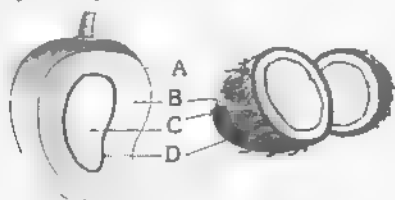
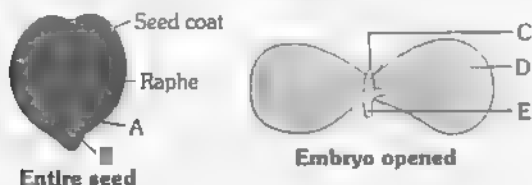


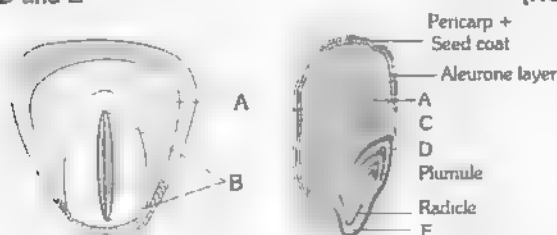
Figure - I

Figure - II

- (a) Epicarp, Mesocarp, Embryo, Endocarp  
(b) Epicarp, Mesocarp, Ovary, Endocarp  
(c) Epicarp, Mesocarp, Ovule, Endocarp  
(d) Epicarp, Mesocarp, Seed, Endocarp
72. The following diagram is the typical structure of dicotyledonous seeds. In which one of the options all the five parts A to E are correctly identified [NCERT]



- (a) A - Hilum, B - Micropyle, C - Plumule, D - Radicle, E - Cotyledon  
(b) A - Micropyle, B - Hilum, C - Plumule, D - Cotyledon, E - Radicle  
(c) A - Hilum, B - Micropyle, C - Plumule, D - Cotyledon, E - Radicle  
(d) A - Hilum, B - Micropyle, C - Radicle, D - Cotyledon, E - Plumule
73. The following diagram is the typical structure of monocotyledonous seeds. Identify all the five parts A, B, C, D and E [NCERT]



- (a) A - Embryo, B - Endosperm, C - Scutellum, D - Coleorrhiza, E - Coleoptile  
(b) A - Endosperm, B - Embryo, C - Scutellum, D - Coleoptile, E - Coleorrhiza  
(c) A - Embryo, B - Endosperm, C - Scutellum, D - Coleoptile, E - Coleorrhiza  
(d) A - Endosperm, B - Embryo, C - Scutellum, D - Coleorrhiza, E - Coleoptile
74. Non-albuminous seed is produced in [CBSE PMT 2014]  
(a) Wheat (b) Pea  
(c) Maize (d) Castor

### Dispersal of fruits and seeds

1. The most common method for dispersal of fruits and seeds in legumes is  
(a) Autochory (b) Anemichory  
(c) Zoochory (d) Hydrochory
2. Bright coloured fleshy fruits are dispersed by [Odisha JEE 2008]

Or

Seeds of Mulberry are dispersed by

- (a) Insect (b) Air  
(c) Water (d) Bird
3. Parachute mechanism of seed dispersal occurs in [MHCET 2003]

Or

Seeds are dispersed by wind in

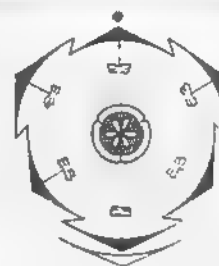
- (a) Xanthium (b) Calotropis  
(c) Mango (d) Apple
4. Hairy styles are present in  
(a) *Ranunculus* (b) *Clematis*  
(c) *Mucuna* (d) *Polygonum*
5. Dispersal by explosive fruits is shown by  
(a) *Barleria* (b) *Impatiens* and *Ruellia*  
(c) *Acanthus* and *Phlox* (d) All of these
6. In *Ruellia* and *Justicia* dispersal of seeds takes place by  
(a) Jaculator mechanism (b) Censer mechanism  
(c) Winged seeds (d) Parachute mechanism
7. Seed dispersal by parachute type mechanism is found in [CPMT 1998; MP PMT 2013]  
(a) Pea of Fabaceae  
(b) Mustard of Brassicaceae  
(c) Cotton of Malvaceae  
(d) *Taraxacum* of Asteraceae / compositeae
8. The fruits and seeds which are either sticky, have different types of outgrowths are capable of undergoing  
(a) Forced zoochory (b) Compensated zoochory  
(c) Hydrochory (d) Anemochory
9. The dispersal of cotton and madar seeds takes place by wind because of  
(a) Wings (b) Hairs  
(c) Pappus (d) Bracts
10. In which of the following plants dispersal of fruits takes place by parachute mechanism  
(a) *Terminalia* (b) *Tagetes*  
(c) *Moringa* (d) *Acer*
11. The fruits of *Xanthium* are dispersed by animals because  
(a) These are having sticky substance  
(b) These are edible  
(c) These are provided with hooks  
(d) These are light in weight
12. An example of fruit which is dispersed by bird is  
(a) *Calotropis* (b) *Mirabilis*  
(c) *Argemone* (d) *Bignonia*

13. In *Rafflesia*, seeds are dispersed by  
(a) Wind (b) Elephant  
(c) Mites (d) Flies
14. An example of compensated Zoochory is  
(a) Mango (b) Apricot  
(c) Tomato (d) All of these
15. In drumstick the seeds are dispersed by [DPMT 2006]  
(a) Water (b) Animals  
(c) Wind (d) Explosive mechanism
16. Aril helps in  
(a) Buoyancy to seeds of *Nymphaea* to float in water  
(b) Dispersal in litchi by animals  
(c) None as it is an edible part  
(d) Both (a) and (b)
17. Winged seeds occur in  
(a) *Chorea* (b) *Moringa*  
(c) *Cotton* (d) *Calotropis*
18. Dispersal of fruits in Opium (poppy) occurs through shaking by wind by [CPMT 2000]  
(a) Explosive mechanism (b) Parachute mechanism  
(c) Censer mechanism (d) Jacular mechanism
19. Some plants have a habit of harbouring ants to save the plants from damage by other animals which is known as [Kerala PMT 2006]  
(a) Entomophily (b) Myrmecophily  
(c) Anemophily (d) Hydrophily  
(e) Zoophily

### Taxonomy of Angiospermic plants

1. The correct floral formula of Liliaceae is [RPMT 1992; APME 1992; CPMT 1993, 97]  
(a)  $\oplus \overline{\sigma} P_{3+3} A_6 \underline{G}_{(3)}$  (b)  $\text{Br} \oplus \overline{\sigma} P_{3+3} A_{3+3} \underline{G}_{(3)}$   
(c)  $\dagger \overline{\sigma} P_{3+3} A_{3+3} \underline{G}_{(3)}$  (d)  $\dagger \overline{\sigma} P_{3+3} A_{3+3} \underline{G}_{(6)}$
2. The two families dominate in having maximum useful plants [Pb. PMT 1993; CBSE PMT 1997]  
(a) Fabaceae and Poaceae  
(b) Liliaceae and Solanaceae  
(c) Malvaceae and Brassicaceae  
(d) Liliaceae and Poaceae
3. The systematic position of Cucurbitaceae according to Bentham and Hooker's system  
(a) Thalamiflorae, Parietales (b) Inferae, Asterales  
(c) Calyciflorae, Rosales (d) Calyciflorae, Passiflorales
4. Touch me not belongs to [RPMT 1995]  
(a) Liliaceae (b) Solanaceae  
(c) Mimosoideae (d) Malvaceae
5. Which of the following families is characterised by the presence of perianth  
(a) Malvaceae (b) Liliaceae  
(c) Cruciferae (d) Solanaceae

6.



Plants having the above given floral diagram are

[AIIMS 2012]

- (a) Leguminous  
(b) Dicots  
(c) Medicinal and perennial  
(d) Having pinnately compound leaves
7. The host for *Cercospora personata* belongs to this family of angiosperms [KCET 2012]  
(a) Gramineae (b) Leguminosae  
(c) Malvaceae (d) Asclepiadaceae
8. Which of the following is phylogenetically most advanced of the dicotyledonous families [Odisha JEE 2005]  
(a) Acanthaceae (b) Scrophulariaceae  
(c) Compositae (d) Umbelliferae
9. The androecium of Malvaceae is [RPMT 1996; AFMC 1994; AMU (Med.) 1997]  
(a) Didynamous (b) Tetradynamous  
(c) Diadelphous (d) Monadelphous
10. Rutaceae differs from Malvaceae in having [BHU 1997]  
(a) Simple leaves  
(b) Polypetalous corolla  
(c) Syncarpous, superior ovary  
(d) Obdiplostemonous stamens
11. Which statement is wrong for compositae [CPMT 1998]  
(a) 5-lobed stamens (b) Syngenesious stamens  
(c) Basal ovule (d) Ligulate ray florets
12. Red Gram is  
(a) *Phaseolus aureus* (b) *Cicer arletinum*  
(c) *Cajanus cajan* (d) *Phaseolus mungo*
13. Match the following and choose the correct combination from the options given
- | Column I<br>(Family)         | Column II<br>(Androecium formula) |
|------------------------------|-----------------------------------|
| (A) Brassicaceae/ cruciferae | 1. $A_{3+3}$                      |
| (B) Fabaceae                 | 2. $A_{(5)}$                      |
| (C) Solanaceae               | 3. $A_{(9)+1}$                    |
| (D) Liliaceae                | 4. $A_{2+4}$                      |
- [CPMT 1997; AIIMS 2001; Kerala PMT 2012]
- (a) A-4, B-3, C-2, D-1 (b) A-1, B-2, C-3, D-4  
(c) A-2, B-3; C-4, D-1 (d) A-3, B-4, C-1, D-2  
(e) A-4, B-3, C-1, D-2
14. Millets belong to [APMEE 1994]  
(a) Fabaceae (b) Poaceae  
(c) Liliaceae (d) Asteraceae

15. Commissural stigma (Along carpellary cohesion plane) occurs in family [APMEE 1994]

(a) Solanaceae (b) Liliaceae  
(c) Cruciferae (d) Fabaceae

16. *Carthamus tinctorius* belongs to family  
(a) Asteraceae (b) Solanaceae  
(c) Malvaceae (d) Fabaceae

17. Botanical name of Cauliflower is [CBSE PMT 1991]

(a) *Brassica oleracea* var. *capitata*  
(b) *Brassica campestris*  
(c) *Brassica oleracea* var. *botrytis*  
(d) *Brassica oleracea* var. *gemmifera*

18. Plants are always herbs in  
(a) Fabaceae (b) Solanaceae  
(c) Brassicaceae (d) None of these

19. See the following figures and identify the given below species belong to which of the following families respectively [NCERT]



*Pisum Sativum* (pea) *Solanum nigrum* (mokoi) *Allium cepa* (Onion)

(a) Solanaceae, Fabaceae, Liliaceae  
(b) Compositae, Malvaceae, Liliaceae  
(c) Fabaceae, Solanaceae, Liliaceae  
(d) Liliaceae, Compositae, Malvaceae

20. A family delimited by type of inflorescence is [CBSE PMT 1990]

Or

A family belongs to inferae and gamopetalae

(a) Fabaceae (b) Asteraceae  
(c) Solanaceae (d) Liliaceae

21. Axile placentation occurs in  
(a) Asteraceae and Fabaceae  
(b) Brassicaceae and Solanaceae  
(c) Solanaceae and Liliaceae  
(d) All of these

22. A diagnostic trait for identification of fabaceous flower is [NCERT]

(a) Tetradynamous androecium  
(b) Inferior ovary  
(c) Cruciform corolla  
(d) Vexillary aestivation

23. Which of the following is not correctly paired [AMU (Med.) 2010]

(a) Fabaceae : Legume family  
(b) Solanaceae : Potato family  
(c) Liliaceae : Sunflower family  
(d) Brassicaceae : Mustard family

24. Botanical name of Finger Millet is

(a) *Sorghum vulgare* (b) *Eleusine coracana*  
(c) *Amaranthus viridis* (d) *Pennisetum typhoides*

25. Flower of Fabaceae is [JIPMER 2002]

(a) Complete, zygomorphic, pentamerous  
(b) Complete, actinomorphic, trimerous  
(c) Incomplete, zygomorphic, trimerous  
(d) Incomplete, actinomorphic, pentamerous

26. Most important character of *Brassica campestris* is [AFMC 1992; APMEE 1995; RPMT 2002]

(a) False septum (b) Parietal placentation  
(c) Ebracteate (d) Imbricate aestivation

27. In fabaceae, one of the following immediately encloses the essential organs [APMEE 2002]

(a) Anterior petals (b) Posterior petal  
(c) Lateral petals (d) Sepals

28. Given diagram shows the cohesion of stamens. It is the characteristic of pulse family. Identify the type of cohesion [NCERT]



(a) Synandrous (b) Polyadelphous  
(c) Diadelphous (d) Monoadelphous

29. Four sepals arranged in two whorls is characteristic of family [Manipal 2001; BHU 2002]

(a) Solanaceae (b) Fabaceae  
(c) Brassicaceae (d) Liliaceae

30. Andromonoecious guggal (*Commiphora wightii*) plants population are those that [MP PMT 2013]

(a) Produce more male flower bearing plants and a few female flower bearing plants in a population  
(b) Produce more female flower bearing plants and a few male flower bearing plants in a population  
(c) Produce male flowers bearing plants and female flowers bearing plants in equal number in a population  
(d) Produce both male and bisexual flower bearing individual in a population

31. Largest family of flowering plants is [Tamil Nadu 2001]

Or

Compositae is also known as [DPMT 2001]

(a) Fabaceae (b) Thalamiflorae  
(c) Poaceae (d) Asteraceae

32. Family Fabaceae belongs to series [APMEE 1996]

(a) Inferae (b) Thalamiflorae  
(c) Calyciflorae (d) Disciflorae

33. Familiar examples of family Liliaceae are [KCET 1995; Pb. PMT 1999; RPMT 1999]

(a) *Allium cepa*, *Aloe vera* and *Tamarindus indica*  
(b) *Saraca indica*, *Allium cepa* and *Aloe vera*  
(c) *Allium sativum*, *Allium cepa* and *Aloe vera*  
(d) *Tamarindus indica*, *Allium cepa* and *Allium sativum*

34. Which one is odd [CPMT 1993]  
(a) *Allium cepa* (b) *Helianthus annuus*  
(c) *Brassica juncea* (d) *Arachis hypogea*
35. Scientific name of Sunflower is [WB JEE 2009]  
(a) *Brassica campestris* (b) *Pisum sativum*  
(c) *Helianthus annuus* (d) *Gossypium herbaceum*
36. *Colchicum autumnale* is a member of [NCERT; CPMT 2010]  
Or  
Colchicine is obtained from which of the following families [AFMC 2012]  
(a) Brassicaceae (b) Liliaceae  
(c) Poaceae (d) Fabaceae
37. A weed belonging to family Asteraceae which has spread in all parts of India is  
(a) *Nicotiana* (b) *Oryza*  
(c) *Parthenium* (d) *Hordeum*
38. Epipetalous and syngenesious stamens occur in [CBSE PMT 1991, 92; VITEEE 2008; Odisha JEE 2009]  
(a) Solanaceae (b) Brassicaceae  
(c) Fabaceae (d) Asteraceae
39. Carbohydrate rich food is got from  
(a) Brassicaceae (b) Poaceae  
(c) Fabaceae (d) Asteraceae
40. *Raphanus* belongs to  
(a) Asteraceae (b) Brassicaceae  
(c) Solanaceae (d) Liliaceae
41. A crop plant which can grow well even in nitrogen deficient soil is  
(a) *Helianthus annuus* (b) *Gossypium herbaceum*  
(c) *Brassica campestris* (d) *Cajanus cajan*
42. Bicarpellary, syncarpous, unilocular ovary with basal placentation occurs in [Tamil Nadu 2001]  
(a) Liliaceae (b) Solanaceae  
(c) Asteraceae (d) Fabaceae
43. Pulses are obtained from [NCERT; CBSE PMT 1993; RPMT 1995; KCET 1998; MP PMT 1998, 2000, 02]  
(a) Fabaceae (b) Asteraceae  
(c) Poaceae (d) Solanaceae
44. Find out the correctly matched pair [Kerala PMT 2012]  
(a) Marginal - Tomato  
(b) Axile - Pea  
(c) Parietal - Primrose  
(d) Free Central - Argemone  
(e) Basal - Marigold
45. Masses of pollen grains i.e. pollinia is found in [Odisha JEE 2008]  
(a) Orchidaceae (b) Solanaceae  
(c) Malvaceae (d) Gramineae
46. Which of the following is correct with reference to flowers of family solanaceae [KCET 2003]  
(a) Pentamerous, actinomorphic, unisexual, hypogynous  
(b) Pentamerous, zygomorphic, bisexual, epigynous  
(c) Pentamerous, bisexual, actinomorphic, hypogynous  
(d) Trimerous, actinomorphic, bisexual, hypogynous
47. Mark the correct statement for Gramineae  
(a) The carpel has two styles  
(b) Spikelets are always in pairs  
(c) Palea is the bracteole  
(d) Awn is an appendage of the palea
48. Bicarpellary, syncarpous ovary with axile placentation is seen in [J & K CET 2008]  
(a) Solanaceae (b) Caesalpiniaceae  
(c) Asteraceae (d) Malvaceae
49. The floral formula  $\oplus \overline{\text{K}}_{(5)} \overline{\text{C}}_{(5)} \overline{\text{A}}_5 \overline{\text{G}}_{(2)}$  is that of [CBSE PMT 2009; AIPMT (Cancelled) 2015]  
(a) Tulip (b) Soybean  
(c) Sunnhemp (d) Tobacco / Petunia
50. Replum is present in the ovary of flower of [CBSE PMT 2008]  
(a) Sun flower (b) Pea  
(c) Lemon (d) Brassicaceae Mustard
51. Capitulum is found in the members of the family [MP PMT 2010]  
(a) Ranunculaceae (b) Solanaceae  
(c) Asteraceae (d) Labiatae
52. An example of liliaceae family is [NCERT; AMU (Med.) 2009]  
(a) Lupin (b) Soyabean  
(c) *Petunia* (d) Tulip
53. Which of the following represents the floral characters of Liliaceae [NCERT; BHU 2005; Kerala PMT 2008]  
(a) Six tepals, zygomorphic, six stamens, bilocular ovary, axile placentation  
(b) Tetramerous, actinomorphic, polyphyllous, unilocular ovary, axile placentation  
(c) Trimerous, actinomorphic, polyandrous, Superior ovary, axile placentation  
(d) Bisexual, zygomorphic, gamophyllous, inferior ovary, marginal placentation  
(e) Unisexual, actinomorphic, trilocular, inferior ovary, axile placentation
54. *Datura* belongs to [AFMC 1996]  
(a) Compositae (b) Labiatae  
(c) Malvaceae (d) Solanaceae
55. Vexillary aestivation is characteristic of the family [NCERT; CBSE PMT (Pre.) 2012; Odisha JEE 2012]  
(a) Fabaceae (b) Asteraceae  
(c) Solanaceae (d) Brassicaceae
56. Petals possess claw in  
(a) Solanaceae (b) Liliaceae  
(c) Malvaceae (d) Cruciferae
57. Family Gramineae is closely related to [Odisha JEE 2005]  
(a) Cannaceae (b) Cyperaceae  
(c) Arecaceae (d) Apicaceae
58. Which of the family possess perianth of six coloured tepals  
(a) Mimosoideae (b) Solanaceae  
(c) Liliaceae (d) Malvaceae



59. Marginal placentation is found in [Chd. CET 1997]  
 (a) Solanaceae (b) Cruciferae  
 (c) Fabaceae/Leguminosae (d) Asteraceae/Compositae
60. Select the incorrect match from the following [Odisha JEE 2010]  
 (a) Mimosaceae – kiker (b) Malvaceae - hollyhock  
 (c) Fabaceae – alfalfa (d) Caesalpiniaceae- catechu
61. Consider the following four statements A, B, C and D and select the right option for two correct statements  
**Statements**  
 (A) In vexillary aestivation, the large posterior petal is called – standard, two lateral ones are wings and two small anterior petals are termed keel  
 (B) The floral formula for Liliaceae is  $\oplus \overline{\text{P}}_{3+3} \overline{\text{A}}_{3+3} + \underline{\text{G}}_3$   
 (C) In pea flower the stamens are monadelphous  
 (D) The floral formula for Solanaceae is  $\oplus \overline{\text{K}}_{(3)} \overline{\text{C}}_{(3)} \overline{\text{A}}_{(4)} + \underline{\text{G}}_{(2)}$   
 The correct statements are [CBSE PMT (Main) 2010]  
 (a) (A) and (C) (b) (A) and (B)  
 (c) (B) and (C) (d) (C) and (D)
62. Staminodes occur in family [RPMT 1995, 96]  
 (a) Papilionatae/Arachis (b) Malvaceae/Hibiscus  
 (c) Caesalpinoideae/Cassia (d) Cruciferae/Iberis
63. Cruciferae differ from Malvaceae in the presence of [CBSE PMT 1992]  
 (a) Bicarpellary unilocular ovary and silique fruit  
 (b) Multicarpellary multilocular ovary and capsule fruit  
 (c) Monocarpellary, multilocular ovary with capsule fruit  
 (d) Multicarpellary unilocular ovary and cypsella fruit
64. Which of the family does not possess axile placentation [RPMT 1992, 95, 96]  
 (a) Solanaceae (b) Malvaceae  
 (c) Leguminosae/Cruciferae (d) Liliaceae
65. Perigynous condition is common among  
 (a) Liliaceae (b) Solanaceae  
 (c) Leguminosae (d) Malvaceae
66. Which of the following is/are not characteristic features of Asteraceae  
 (A) Cypsela type of fruit  
 (B) Syngenesious stamens  
 (C) Ovary bicarpellary and superior  
 (D) Placentation marginal  
 (E) Head type of inflorescence [Kerala PMT 2008]  
 (a) (B), (C) and (D) only (b) (C) and (E) only  
 (c) (C) and (D) only (d) (A) and (B) only  
 (e) (C) only
67. Gynostegium (Fusion of anthers with stigma) and pollinia are present in family [AMU (Med.) 1997; Odisha JEE 2009]  
 (a) Apocynaceae  
 (b) Asclepiadaceae  
 (c) Convolvulaceae  
 (d) Solanaceae/Cucurbitaceae
68. Placentation in tomato and lemon is [CBSE PMT (Pre.) 2012]  
 (a) Parietal (b) Free central  
 (c) Marginal (d) Axile
69. The typical floral formula of Papilionaceae (Soybean) is [CBSE PMT (Main) 2010; BHU 2012]  
 (a)  $\oplus \overline{\text{K}}_{(5)} \overline{\text{C}}_{(5)} \overline{\text{A}}_5 \underline{\text{G}}_2$  (b)  $\oplus \overline{\text{K}}_{(5-4)} \overline{\text{C}}_{(5-4)} \overline{\text{A}} \underline{\text{G}}_5$   
 (c)  $\% \overline{\text{K}}_{(5)} \overline{\text{C}}_{1+2+(2)} \overline{\text{A}}_{1+(9)} \underline{\text{G}}_1$  (d)  $\% \overline{\text{K}}_{(5)} \overline{\text{C}}_5 \overline{\text{A}}_{10} \underline{\text{G}}_1$
70. Floral formula of mustard (or) Cruciferae is [RPMT 1992, 95, 96, 97; Kerala PMT 2010]  
**Or**  
 Floral formula of *Brassica campestris* is [AIIMS 2010]  
 (a)  $\oplus \overline{\text{K}}_{(5)} \overline{\text{C}}_{(5)} \overline{\text{A}}_5 \underline{\text{G}}_{(2)}$   
 (b)  $\text{Ebr} \oplus \overline{\text{K}}_{2+2} \overline{\text{C}}_4 \overline{\text{A}}_{2+4} \underline{\text{G}}_{(2)}$   
 (c)  $\oplus \overline{\text{K}}_5 \overline{\text{C}}_5 \overline{\text{A}}_{(5)} \underline{\text{G}}_{(2)}$   
 (d)  $\oplus \overline{\text{K}}_5 \overline{\text{C}}_5 \overline{\text{A}}_5 \underline{\text{G}}_{(2)}$
71. Family Podostemaceae is placed under the series [Kerala PMT 2008]  
 (a) Multiovulatae aquaticae (b) Microembryae  
 (c) Daphnales (d) Unisexuales  
 (e) Heteromerae
72. The family containing mustard, and its main characters are [AIIMS 2005]  
 (a) Brassicaceae-Tetramerous flowers, six stamens, bicarpellary gynoeceum, silique type fruit  
 (b) Brassicaceae-Pentamerous flowers, many stamens, pentacarpellary gynoeceum, capsule type fruit  
 (c) Solanaceae-Pentamerous flowers, five stamens, bicarpellary gynoeceum, berry type fruit  
 (d) Poaceae-Trimerous flowers, three stamens, monocarpellary gynoeceum, caryopsis type of fruit
73. The presence of corollary corona, sagittate anthers and dumb-bell shaped stigma are the characteristic features of ..... [KCET 2010]  
 (a) *Musa paradisiaca*  
 (b) *Hibiscus rosa-sinensis*  
 (c) *Catharanthus roseus*  
 (d) *Ravenala madagascariensis*
74. Inflorescence of family compositae is [Odisha JEE 2004]  
 (a) Perianth (b) Iodicule  
 (c) Capitulum (d) Hypanthodium
75. Beet root (*Beta vulgaris*) belongs to family [Odisha JEE 2004]  
 (a) Apocynaceae (b) Cruciferae  
 (c) Chenopodiaceae (d) Asclepiadaceae

76. Sunflower belongs to the family [DUMET 2009]  
(a) Liliaceae (b) Asteraceae  
(c) Cruciferae (d) Fabaceae
77. Monoadelphous condition of stamens is found in [BHU 2004]  
(a) Malvaceae (b) Cyperaceae  
(c) Cruciferae (d) Solanaceae
78. Tetradyamous condition is found in [NCERT; CPMT 2004; AFMC 2004]  
(a) *Hibiscus rosa-sinensis* (b) *Petunia hybrida*  
(c) *Helianthus annuus* (d) *Brassica campestris*
79. Diadelphous stamens are the characteristic feature of [CPMT 2004]  
(a) Ranunculaceae (b) Fabaceae  
(c) Poaceae (d) Malvaceae
80. The distinct features of fabaceae are [Kerala PMT 2012]  
(a) Zygomorphic, diadelphous and monocarpellary  
(b) Actinomorphic, monadelphous and monocarpellary  
(c) Zygomorphic, monadelphous and pentacarpellary  
(d) Zygomorphic, polyadelphous and tricarpeal  
(e) Zygomorphic, diadelphous and bicarpellary
81. Underground food is stored in [RPMT 1995]  
(a) Solanaceae and Leguminosae  
(b) Liliaceae and Cruciferae  
(c) Cruciferae and Solanaceae  
(d) Solanaceae and Malvaceae
82. The botanical name of Satawar is  
(a) *Smilax* (b) *Asparagus*  
(c) *Yucca* (d) *Lilium*
83.  $\oplus \frac{\sigma}{\tau} K_{2+2} C \times 4 A_{2+4} \underline{G_{(2)}}$  is floral formula of [CBSE PMT 1993]  
(a) *Allium cepa* (b) *Solanum nigrum*  
(c) *Helianthus annuus* (d) *Brassica nigra*
84. Tetradyamous condition is characteristics of [NCERT; RPMT 1993; EAMCET 1993; AMU (Med.) 1997; CBSE PMT 2001; Bihar PMT 2001; Odisha JEE 2011]  
(a) Liliaceae/*Allium*/*Asphodelus*  
(b) Cruciferae/*Mustard*/*Iberis*  
(c) Malvaceae/*Althea*/*Hibiscus*  
(d) Solanaceae/*Nicotiana*/*Petunia*
85. Floral formula of Caesalpinoideae is  
(a)  $\oplus \frac{\sigma}{\tau} K_5 C_{(5)} A_{1+9} \underline{G_1}$  (b)  $\oplus \frac{\sigma}{\tau} K_{(5)} C_{(5)} A_5 \underline{G_1}$   
(c)  $\% \frac{\sigma}{\tau} K_5 C_{(5)} A_{10} \underline{G_1}$  (d)  $\text{Br} \% \frac{\sigma}{\tau} K_5 C_5 A_{5+5} \underline{G_1}$
86. Bilocular oblique ovary with numerous shining ovule on swollen axile placenta is the characteristics of [APMEE 1994; AMU (Med.) 2002; DPMT 2004; J & K CET 2012]  
(a) Cruciferae (b) Solanaceae  
(c) Liliaceae (d) Malvaceae
87. The division of Leguminosae into its sub families is based upon (or) the Leguminosae is distinguished on the basis of  
(a) K and C (b) K and A  
(c) C and A (d) A and G
88. Legume plants are important for atmosphere because they [RPMT 2005, 06]  
(a) Help in  $\text{NO}_2$  fixation  
(b) Do not help in  $\text{NO}_2$  fixation  
(c) Increase soil fertility  
(d) All of these
89. Which of the following are not characteristic features of fabaceae [Kerala CET 2005]  
(a) Tap root system, compound leaves and raceme inflorescence  
(b) Flowers actinomorphic, twisted aestivation and gamopetalous  
(c) Stamens 10, introrse, basifixed, ditheous  
(d) Monocarpellary, ovary superior and bent stigma  
(e) Fruit is legume
90. Which of the following member of family Solanaceae is rich in source of vitamin C [AFMC 2005]  
(a) Guava (b) Tomato  
(c) Gooseberry (d) Strawberry
91. Lady finger belongs to family [BHU 2005; CPMT 2009]  
(a) Malvaceae (b) Cucurbitaceae  
(c) Liliaceae (d) Brassicaceae
92. Botanical name of 'chana' is [BHU 2005]  
(a) *Cicer arietinum* (b) *Phaseolus aureus*  
(c) *Lablab purpureus* (d) *Dolichos*
93. The characteristic type of placentation found in the members of caryophyllaceae is [Kerala PMT 2009]  
(a) Parietal (b) Marginal  
(c) Basal (d) Axile  
(e) Free central
94. Which of the following represents the condition seen in the family compositae [Manipal 2005]  
(a) Superior ovary, syngenesious, single basal ovule  
(b) Inferior ovary, monadelphous, basal placentation  
(c) Inferior ovary, syngenesious, axile, placentation  
(d) Syngenesious, basal placentation and epigynous
95. From the options given below, find out the correct floral formula for a flower having the following characters namely actinomorphic, bisexual, five united sepals, five united petals, stamens five and epipetalous, bicarpellary, syncarpous with superior ovary [Kerala PMT 2011]  
(a)  $\oplus \frac{\sigma}{\tau} K_{(5)} C_{(5)} A_5 \underline{G_{(2)}}$  (b)  $\oplus \frac{\sigma}{\tau} K_{(5)} \overline{C_{(5)} A_{(5)}} \underline{G_{(2)}}$   
(c)  $\oplus \frac{\sigma}{\tau} K_{(5)} C_{(5)} A_{(5)} \underline{G_{(2)}}$  (d)  $\oplus \frac{\sigma}{\tau} K_{(5)} \overline{C_{(5)} A_{(5)}} \overline{G_{(2)}}$   
(e)  $\oplus \frac{\sigma}{\tau} K_{(5)} C_{(5)} A_{(5)} \overline{G_{(2)}}$
96. Fruit in members of solanaceae is [CPMT 2005]  
(a) Drupe (b) Capsule or berry  
(c) Siliqua (d) Pod or achene

97. Observe the given floral diagram and choose the suitable floral formula from the followings [Kerala PMT 2006]



- (a)  $\% \bar{\sigma} K_5 C_5 A_{10} \underline{G}_1$   
 (b)  $\% \bar{\sigma} K_{(5)} C_5 A_{10} \underline{G}_1$   
 (c)  $\% \bar{\sigma} K_{(5)} C_{1+2+(2)} A_{(9)+1} \underline{G}_{(1)}$   
 (d)  $\% \bar{\sigma} K_5 C_{1+2+(2)} A_{(9)+1} \underline{G}_{(1)}$   
 (e)  $\% \bar{\sigma} K_{(5)} C_5 A_{(9)+1} \underline{G}_{(1)}$
98. Match the item in column I with column II and choose the correct answer

Column I		Column II	
A	Microspermae	1	Alismaceae
B	Epigynae	2	Liliaceae
C	Calycinae	3	Iridaceae
D	Apocarpae	4	Orchidaceae
E	Coronarieae	5	Palmae

[Kerala PMT 2006]

- (a) A - 2, B - 3, C - 4, D - 5, E - 1  
 (b) A - 3, B - 4, C - 5, D - 1, E - 2  
 (c) A - 4, B - 3, C - 5, D - 1, E - 2  
 (d) A - 1, B - 2, C - 3, D - 4, E - 5  
 (e) A - 5, B - 4, C - 3, D - 2, E - 1
99. The floral formula of solanaceae (Chilli) is

[NCERT; Bihar CECE 2006; CBSE PMT (Pre.) 2011]

- (a)  $E_{br} \bar{\sigma} K_{(5)} C_{(5)} A_5 \underline{G}_{(2)}$   
 (b)  $E_{br} \bar{\sigma} K_{(4)} C_{2+2} A_{2+4} \underline{G}_{(2)}$   
 (c)  $E_{br} \bar{\sigma} K_{(5)} C_5 A_5 \underline{G}_{(5)}$   
 (d)  $Br \% K_{(5)} C_{(5)} A_{(10)} \underline{G}_1$

100. In the members of family malvaceae, anthers are described as [NCERT; KCET 2006]

- (a) Diadelphous and ditheous  
 (b) Diadelphous and monothecous  
 (c) Monadelphous and ditheous  
 (d) Monadelphous and monothecous
101. Pentamerous actinomorphic flowers, bicarpellary ovary with oblique septa, and fruit a capsule or berry, are characteristic features of [NCERT; CBSE PMT 2006]
- (a) Solanaceae (b) Liliaceae  
 (c) Asteraceae (d) Brassicaceae
102. What type of placentation is seen in sweet pea [CBSE PMT 2006]

- (a) Free central (b) Marginal  
 (c) Basal (d) Axile

103. Aloe used in Medicine belong to family [NCERT; Bihar CECE 2006]

- (a) Liliaceae (b) Solanaceae  
 (c) Malvaceae (d) Asteraceae

104. Which one of the following series include the orders ranales, parietales and malvales [Kerala PMT 2009]

- (a) Bicarpellatae (b) Thalamiflorae  
 (c) Calyciflorae (d) Disciflorae  
 (e) Inferae

105. Which one of the following represent the floral characters of poaceae [Kerala PMT 2009]

- (a) Pedicellate, bracteate, bisexual, tetramerous, actinomorphic, complete and superior ovary  
 (b) Pedicellate, bracteate, bisexual, pentamerous, zygomorphic complete and superior ovary  
 (c) Sessile, bracteate, bracteolate, incomplete, uni or bisexual, perianth modified into lodicules, stamens three, syncarpous, superior ovary and feathery stigma  
 (d) Bracteate, unisexual actinomorphic, stamens five and inferior ovary  
 (e) Bracteate, bracteolate, bisexual, pentamerous, actinomorphic, complete and superior ovary

106. Select the characters which are not applicable to the family solanaceae

- (i) Epipetalous and syngenesious anthers  
 (ii) Bicarpellary and syncarpous ovary  
 (iii) Oblique ovary with axile placentation  
 (iv) Stamens six, arranged in two whorls  
 (v) Bicarpellary, syncarpous and inferior ovary

[Kerala PMT 2009]

- (a) (ii) and (iii) only (b) (i), (iv) and (v) only  
 (c) (ii), (iv) and (v) only (d) (i) and (iii) only  
 (e) (iii), (iv) and (v) only

107. Tricarpellary syncarpous gynoecium is found in flowers of

[NEET (Phase-I) 2016]

- (a) Liliaceae (b) Solanaceae  
 (c) Fabaceae (d) Poaceae

## NCERT Exemplar Questions

1. Rearrange the following zones as seen in the root in vertical section and choose the correct option

- A. Root hair zone B. Zone of meristems  
 C. Rootcap zone D. Zone of maturation  
 E. Zone of elongation

Options: [NCERT]

- (a) C, B, E, A, D (b) A, B, C, D, E  
 (c) D, E, A, C, B (d) E, D, C, B, A

2. In an inflorescence where flowers are borne laterally in an acropetal succession, the position of the youngest floral bud shall be [NCERT]

- (a) Proximal (b) Distal  
 (c) Intercalary (d) Any where

3. The mature seeds of plants such as gram and peas, possess no endosperm, because [NCERT]

- (a) These plants are not angiosperms  
 (b) There is no double fertilization in them  
 (c) Endosperm is not formed in them  
 (d) Endosperm gets used up by the developing embryo during seed development

4. Match the followings and choose correct option

**Group A**

- A. Aleurone layer  
B. Parthenocarpic fruit  
C. Ovule  
D. Endosperm

**Group B**

- i. Without fertilization  
ii. Nutrition  
iii. Double fertilization  
iv. Seed

Option:

[NCERT]

- (a) A-i, B-ii, C-iii, D-iv  
(b) A-ii, B-i, C-iv, D-iii  
(c) A-iv, B-ii, C-i, D-iii  
(d) A-ii, B-iv, C-i, D-iii

5. Venation is a term used to describe the pattern of arrangement of [NCERT]

- (a) Floral organs  
(b) Flower in inflorescence  
(c) Veins and veinlets in a lamina  
(d) All of them

6. Endosperm, a product of double fertilization in angiosperms is absent in the seeds of [NCERT]

- (a) Gram (b) Orchids  
(c) Maize (d) Castor

7. Which of the following plants is used to extract the blue dye [NCERT]

- (a) *Trifolium* (b) *Indigofera*  
(c) *Lupin* (d) *Cassia*

8. The placenta is attached to the developing seed near the [NCERT]

- (a) Testa (b) Hilum  
(c) Micropyle (d) Chalaza

3. The floral formula of the given floral diagram is



[Kerala PMT 2007]

- (a)  $Br K_{Pappus} C_{(5)} A_0 G_{(2)}$   
(b)  $Br \overline{Q} K_{Pappus} C_{(5)} A_{(5)} G_{(1)}$   
(c)  $Br \overline{Q} K_{5(Pappus)} \overline{C_{(5)} A_{(5)}} G_{(2)}$   
(d)  $Br \overline{Q} K_{Pappus} \overline{C_{(5)} A_{(5)}} G_{(2)}$   
(e)  $Br \overline{Q} K_{Pappus} \overline{C_5 A_5} G_{(2)}$

4. Study the following lists

List-I		List-II	
(A)	Coleorhiza	(I)	Development of sporophyte directly from gametophyte without intervention of gametes
(B)	Apogamy	(II)	Development of gametophyte directly from sporophyte without the involvement of reduction division
(C)	Indusium	(III)	An unbranched columnar stem with a crown of leaves
(D)	Caudex	(IV)	Protective covering of radicle
		(V)	Protective structure of a sorus

The correct match is

[EAMCET 2009]

- | A       | B   | C  | D   |
|---------|-----|----|-----|
| (a) V   | II  | IV | I   |
| (b) IV  | I   | V  | III |
| (c) III | V   | II | IV  |
| (d) II  | III | I  | V   |

5. Fruit of custard apple is [AFMC 2004]

- (a) Etaerio of berries (b) Etaerio of follicles  
(c) Etaerios of achenes (d) Ethaerio of drups

6. Which one of the following organisms is correctly matched with its three characteristics [NCERT; CBSE PMT (Mains) 2012]

- (a) Pea :  $C_3$  pathway, Endospermic seed, Vexillary aestivation  
(b) Tomato : Twisted aestivation, Axile placentation, Berry  
(c) Onion : Bulb, Imbricate aestivation, Axile placentation  
(d) Maize :  $C_3$  pathway, Closed vascular bundles, Scutellum

7. Cladodes are common among

[AMU (Med.) 1999; J &amp; K CET 2008]

- (a) *Liliaceae/Asparagus* and *Ruscus*  
(b) *Opuntia* and *Casurina*  
(c) *Cactus*  
(d) *Euphorbia*

## GT Critical Thinking

### Objective Questions

1. A plant called plantless root is

- (a) *Arceuthobium* (b) *Podostemon*  
(c) *Rafflesia* and *Sapria* (d) All of these

2. Study the following lists

List-I		List-II	
(A)	Spongy aril	(I)	<i>Jussiaea</i>
(B)	Multiple epidermis	(II)	<i>Pistia</i>
(C)	Respiratory roots	(III)	<i>Nerium</i>
(D)	Root pockets	(IV)	<i>Sagittaria</i>
		(V)	<i>Nymphaea</i>

The correct match is

[EAMCET 2009]

- | A      | B   | C   | D   |
|--------|-----|-----|-----|
| (a) I  | III | II  | V   |
| (b) II | I   | IV  | III |
| (c) IV | II  | III | I   |
| (d) V  | III | I   | II  |

8. Identify the incorrect statements from the following  
 P. Cymose inflorescence is found in *Hibiscus* sp  
 Q. Hypanthodium is found in *Ficus benghalensis*  
 R. Synandrous stamen is found in *Calotropis*  
 S. Hesperidium type of fruit is Mango

[WB JEE 2012]

- (a) R, S (b) P, Q  
 (c) Q, R (d) P, S

9. In hypogeal germination due to elongation of ....plumule comes out of the ground [Odisha JEE 2010]

Or

The portion of embryonal axis above cotyledon is called as

[J &amp; K CET 2012]

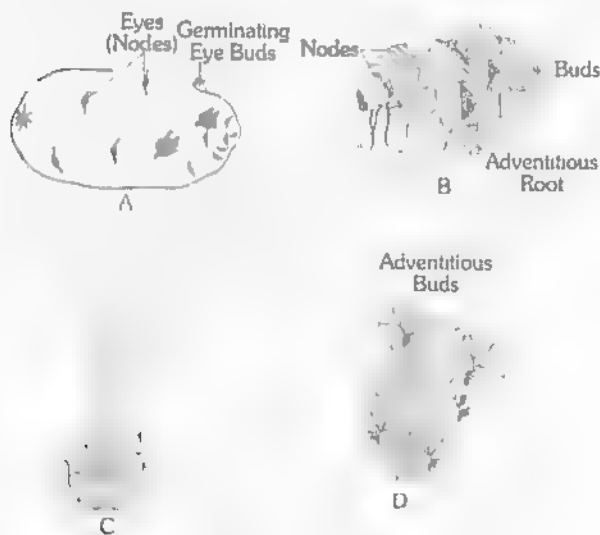
- (a) Hypocotyl (b) Epicotyl  
 (c) Cotyledons (d) Both (a) and (b)

10. Bisexual flowers which never open, demonstrate

[MP PMT 2004]

- (a) Cleistogamy (b) Allogamy  
 (c) Autogamy (d) None of these

11. Study the diagrams given below and select the right options out of (a - d); in which all the 4 items A, B, C and D are correctly identified [NCERT]



- | A          | B       | C      | D         |
|------------|---------|--------|-----------|
| (a) Offset | Sucker  | Stolon | Leaf buds |
| (b) Offset | Sucker  | Stolon | Leaf buds |
| (c) Tuber  | Rhizome | Bulb   | Leaf buds |
| (d) Tuber  | Rhizome | Bulbil | Leaf buds |

12. Which is true about bulbils in Agave

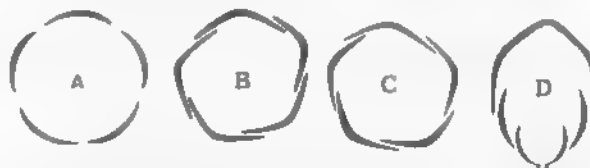
- (a) It has floral buds modified into bulbils  
 (b) Bulbils germinate while still on inflorescence  
 (c) Bulbils show vivipary  
 (d) All the above

13. Transmission tissue is characteristic feature of

[AIPMT (Cancelled) 2015]

- (a) Solid style (b) Dry stigma  
 (c) Wet stigma (d) Hollow style

14. Examine the types of aestivation shown in the following diagram and select the correct answer [NCERT]



- (a) A – Twisted, B – Imbricate, C – Vexillary, D – Valvate  
 (b) A – Imbricate, B – Vexillary, C – Valvate, D – Twisted  
 (c) A – Vexillary, B – Valvate, C – Twisted, D – Imbricate  
 (d) A – Valvate, B – Twisted, C – Imbricate, D – Vexillary

15. Papilionaceous flower with large vexillum covering two wings and the wings covering the keel has corolla aestivation of

- (a) Descending imbricate (b) Ascending imbricate  
 (c) Twisted (d) Valvate

16. An apocarpous flower is found in

[BHU 1999; JIPMER 2000]

- (a) *Caesalpinia* (b) *Ranunculus*  
 (c) *Brassica* (d) *Datura*

17. The side of a flower facing the mother axis is called

[RPMT 1992]

- (a) Anterior side (b) Posterior side  
 (c) Dorsal side (d) Ventral side

18. Which of the following is not a characteristic feature of Fabaceae [NCERT; Kerala PMT 2007]

- (a) Descendingly imbricate, ten stamens, diadelphous, ovary superior  
 (b) Sepals five, gamosepalous, imbricate aestivation, placentation marginal  
 (c) Monocarpellary, ovary superior, style long, slightly bent at the apex  
 (d) Zygomorphic flowers, diadelphous stamens, many ovules  
 (e) Corolla five petals, polypetalous, anterior one large and outermost

19. Stylopodium is present in

- (a) Mustard (b) *Petunia*  
 (c) Coriander (d) Pea

20. Basifixed monothealous anthers (OR) anthers with two microsporangia is characteristics of [RPMT 1995]

- (a) Leguminosae/Pea (b) Malvaceae/Cotton  
 (c) Solanaceae/Tomato (d) Liliaceae/Onion

21. Feathery (hairy) style is persistent in

- (a) *Solanum* (b) *Clematis*  
 (c) *Helianthus* (d) *Hibiscus*

22. In *Acacia* species, the first few leaves are pinnately compound. Then there are leaves with flattened petiole and fewer pinnae. The leaves of adult plant has parallel veined flattened petiole and no pinnae. It shows that

- (a) Leaves of adult plant are reduced to phyllodes while those of the seedling are unreduced  
 (b) The parallel-veined green structures of the adult plant are phylloclades  
 (c) The plant shows developmental heterophylly, compound in seedling and simple in adult plant  
 (d) The leaves of adult plant are unreduced while they are reduced in the seedling stage

23. Hair present on the cob of corn are [CBSE PMT 2000]

Or

Long filamentous threads protruding at the end of a young cob of maize are [CBSE PMT 2006]

- (a) Seed hairs (b) Modified hairs of bracts  
(c) Styles (d) Stigmas and styles

24. Diadelphous stamens occur in [CPMT 1994, 95, 98, 99; Pb. PMT 1997, 99]

- (a) Gramineae (b) Cucurbitaceae  
(c) Papilionatae (d) Malvaceae

25. Inflorescence is [AFMC 1994]

- (a) Composite (multiple) fruit developed from condensed inflorescence  
(b) Aggregate fruit developed from free carpels  
(c) Fruit develop from inferior ovary  
(d) Fruit develops from thalamus

26. Tetradyamous condition is related to [CPMT 1993]

- (a) Androecium (b) Inflorescence  
(c) Perianth (d) Gynoecium

27. Match Column-I with Column-II and select the correct option using the codes given below [NEET (Phase-II) 2016]

Column-I

Column-II

- (A) Pistils fused together (i) Gametogenesis  
(B) Formation of gametes (ii) Pistillate  
(C) Hyphae of higher Ascomycetes (iii) Syncarpous  
(D) Unisexual female flower (iv) Dikaryotic

Codes	(A)	(B)	(C)	(D)
(a)	(iii)	(i)	(iv)	(ii)
(b)	(iv)	(iii)	(i)	(ii)
(c)	(ii)	(i)	(iv)	(iii)
(d)	(i)	(ii)	(iv)	(iii)



## Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

- (a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion  
(b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion  
(c) If the assertion is true but the reason is false  
(d) If both the assertion and reason are false  
(e) If the assertion is false but reason is true

1. Assertion : Roots contain nodes but no leaves or buds.  
Reason : Root branches arise endogenously.  
2. Assertion : In floating aquatic plants, root caps are absent.  
Reason : Root pockets are present in aquatic plants.  
3. Assertion : Root pockets are similar in all terms to root caps.  
Reason : Root caps and root pocket have the ability to regenerate.

4. Assertion

Reason

5. Assertion

Reason

6. Assertion

Reason

7. Assertion

Reason

8. Assertion

Reason

9. Assertion

Reason

10. Assertion

Reason

11. Assertion

Reason

12. Assertion

Reason

13. Assertion

Reason

14. Assertion

Reason

15. Assertion

Reason

16. Assertion

Reason

17. Assertion

Reason

18. Assertion

Reason

19. Assertion

Reason

20. Assertion

Reason

Root hairs are present on whole root surface.

Root hairs absorb water.

In syconous type of fruit, the achenes formed are fewer than the total number of flowers in the inflorescence from which it is formed.

Upper and middle flowers cannot develop into fruits. [EAMCET 2009]

An ascending taxonomic sequence of *Gossypium herbaceum* indicates its placement in progressively higher groups.

Ascending taxonomic hierarchy indicates that a taxon is treated as belonging to a number of taxa. [EAMCET 2009]

Deep feeder tap root system is called cymose tap root system.

Deep feeder root system is found in trees.

Coconut tree is distributed in coastal areas over a large part of the world.

Coconut fruit can float and get dispersed over thousands of kilometers before losing viability. [AIIMS 2004]

Orchis root resembles human hand.

Orchis is an example of fasciculated fleshy roots.

*Momordica* roots look like necklace

*Momordica* possess moniliform roots.

Assimilatory roots can photosynthesize.

Assimilatory roots possess chlorophyll.

Epiphytes are called space parasites.

Epiphytic roots possess velamen.

Maize is an albuminous seed.

Endosperm is completely absorbed by its growing embryo.

In syngenesious stamen, the filaments are fused and the anther are free.

In synandrous stamen, both filaments and anthers are fused.

Stem develops from hypocotyl of embryo.

Internodes bear axillary buds.

Bud may form leaves and flowers.

Bud is a condensed shoot.

In cymose branching, growth of terminal bud stops after some time.

The growth of the main stem is definite.

Ginger has a prostrate-growing rhizome.

Shoot growth is not effected by gravity.

[AIIMS 2004]

Some fruits are furnished with hooks, spines, barbs or other devices for sticking to the body of animals unwillingly.

Such fruits are dispersed by animals unwillingly

Human travellers also disperse seeds and fruits

Generally seeds of economically important crops are introduced to new areas.

21. Assertion : The mesocarp of drupe is edible in all cases.  
Reason : Coconut is a fibrous drupe.
22. Assertion : Thorns of *Artabotrys* are modified floral stalks.  
Reason : In *Antigonon*, the upper floral buds develop thorns.
23. Assertion : Prickles lack vascular cylinder.  
Reason : Prickles show deposition of silica or calcium carbonate.
24. Assertion : Wheat is a caryopsis.  
Reason : Its pericarp is well differentiated.
25. Assertion : Phyllotaxy deals with morphology of leaves.  
Reason : Foliage denotes all leaves of a plant.
26. Assertion : Achenial fruits are single seeded fruits.  
Reason : Capsular fruits are multiseeded fruits.
27. Assertion : In spiral phyllotaxy, many leaves are present on a node.  
Reason : In opposite phyllotaxy, two leaves are borne on a node.
28. Assertion : A simple leaf has undivided lamina.  
Reason : Leaves showing pinnate and palmate venation have various type of incisions.
29. Assertion : *Citrus* is a palmate compound leaf.  
Reason : *Citrus* has single functional leaflet.
30. Assertion : Whole compound leaf of *Clematis* converts into tendril.  
Reason : *Gloriosa superba* shows whole leaf tendril.
31. Assertion : Prickles of plant have a single role of protection of plant.  
Reason : They are superficial in origin.
32. Assertion : Samara is a winged achenial fruit.  
Reason : Wings may or may not develop from its pericarp.
33. Assertion : Small leaflets are present on the phyllode of *Parkinsonia aculeata*.  
Reason : Phyllode does not bear leaves and flowers.
34. Assertion : Persistent sepals of *Physalis* are called accrescent.  
Reason : In Guava, the sepals are marcescent.
35. Assertion : An incomplete flower can be perfect.  
Reason : Perfect flowers (incomplete) are called neuter.
36. Assertion : The flowers of *Hypanthodium* are never exposed.  
Reason : *Hypanthodium* flowers are bisexual.
37. Assertion : Heterophylly is seen in many aquatic plants.  
Reason : Aquatic plants survive in two different conditions of the environment.
38. Assertion : In caducous plants, leaves are never formed.  
Reason : In deciduous plants, all leaves fall together.
39. Assertion : Onion leaves are centric and green.  
Reason : Aerial leaves of onion store food.
40. Assertion : China rose and rose both bear stipules.  
Reason : They are of adnate types.
41. Assertion : Verticillaster is a cymose inflorescence.  
Reason : The main axis and lateral branches of inflorescence end in flowers.
42. Assertion : Leaves of *Bryophyllum*, *Begonia* help in vegetative multiplication.  
Reason : Leaves of these plants possess adventitious buds.
43. Assertion : *Adiantum caudatum* is a walking fern.  
Reason : *Adiantum* grows vegetatively by their leaf tips.
44. Assertion : In corymb, all the flowers lie at the same level.  
Reason : Pedicels of all the flowers are of same length.
45. Assertion : Spathe, a bract of spadix attracts pollinators.  
Reason : Spathe is often brightly coloured.
46. Assertion : Flower of racemose inflorescence are pollinated by insects.  
Reason : In Racemose head inflorescence, the florets are arranged in a centripetal fashion.
47. Assertion : In cymose inflorescence, the main axis ends in a flower, but the lateral axis show continuous growth.  
Reason : The arrangement of flower in this inflorescence is centrifugal
48. Assertion : Compound umbel is branched.  
Reason : In compound umbel, both involucre and involucres are present.
49. Assertion : In cyathium, several male flowers surround a single female flower.  
Reason : The involucre is nectariferous.

## Answers

### Root

1	c	2	b	3	c	4	c	5	c
6	b	7	d	8	c	9	d	10	b
11	a	12	c	13	b	14	d	15	c
16	b	17	c	18	a	19	d	20	d
21	a	22	a	23	d	24	b	25	b
26	a	27	b	28	a	29	a	30	b
31	d	32	a	33	d	34	c	35	d
36	d	37	b	38	d	39	d	40	a
41	c	42	d	43	d	44	c	45	c
46	d	47	b	48	c	49	d	50	b
51	d	52	d						

### Stem

1	b	2	a	3	b	4	c	5	d
6	a	7	b	8	b	9	b	10	d
11	b	12	a	13	c	14	b	15	a

## 366 Morphology of Flowering Plants

16	a	17	d	18	a	19	a	20	a
21	b	22	d	23	b	24	a	25	d
26	a	27	c	28	d	29	c	30	d
31	a	32	d	33	a	34	a	35	c
36	d	37	c	38	d	39	c	40	a
41	b	42	a	43	c	44	d	45	a
46	b	47	b	48	a	49	d	50	d
51	b	52	a						

## Leaf

1	b	2	c	3	b	4	c	5	c
6	d	7	b	8	c	9	d	10	b
11	b	12	b	13	b	14	d	15	d
16	a	17	a	18	c	19	a	20	b
21	a	22	b	23	d	24	d	25	b
26	a	27	a	28	d	29	a	30	b
31	a	32	c	33	b	34	a	35	b
36	a	37	d	38	a	39	a	40	c
41	a	42	b	43	a	44	c	45	a
46	a	47	c	48	a	49	c	50	d
51	a	52	a	53	d	54	c	55	d
56	c	57	a	58	a	59	d		

## Inflorescence

1	a	2	b	3	d	4	d	5	d
6	d	7	a	8	b	9	d	10	a
11	a	12	a	13	a	14	d	15	c
16	c	17	a	18	d	19	c	20	d
21	b	22	a	23	c	24	d	25	d
26	c	27	b	28	a	29	d	30	d
31	d	32	c	33	c				

## Flower

1	d	2	a	3	b	4	a	5	d
6	c	7	c	8	a	9	a	10	a
11	b	12	a	13	c	14	a	15	b
16	c	17	c	18	c	19	d	20	a
21	b	22	c	23	d	24	c	25	c
26	b	27	d	28	c	29	c	30	b
31	a	32	c	33	b	34	d	35	a
36	b	37	c	38	c	39	d	40	a
41	d	42	a	43	d	44	c	45	b
46	b	47	b	48	a	49	b	50	c
51	d	52	c	53	a	54	b	55	c

56	c	57	a	58	c	59	d	60	b
61	a	62	a	63	b	64	b	65	b
66	a	67	a	68	b	69	a	70	b
71	b	72	c	73	b	74	e	75	c
76	c	77	c	78	a	79	c	80	d
81	c	82	d	83	a	84	c	85	d
86	d	87	c	88	a	89	a	90	a
91	a	92	c	93	b	94	d	95	b
96	d	97	b	98	d	99	d	100	a
101	d	102	c	103	d	104	c	105	b

## Seeds and Fruits

1	d	2	c	3	b	4	a	5	c
6	a	7	a	8	a	9	a	10	c
11	b	12	a	13	c	14	b	15	b
16	b	17	a	18	c	19	a	20	c
21	d	22	c	23	a	24	a	25	c
26	c	27	a	28	c	29	d	30	b
31	d	32	b	33	c	34	a	35	d
36	b	37	a	38	d	39	c	40	c
41	a	42	c	43	b	44	e	45	d
46	d	47	d	48	c	49	a	50	b
51	c	52	a	53	d	54	e	55	d
56	c	57	d	58	c	59	b	60	a
61	b	62	a	63	d	64	b	65	b
66	a	67	a	68	b	69	c	70	a
71	d	72	c	73	b	74	b		

## Dispersal of fruits and seeds

1	a	2	d	3	b	4	b	5	d
6	a	7	d	8	a	9	b	10	b
11	c	12	d	13	b	14	d	15	c
16	d	17	b	18	c	19	b		

## Taxonomy of Angiospermic plants

1	b	2	a	3	d	4	c	5	b
6	c	7	b	8	c	9	d	10	d
11	a	12	c	13	a	14	b	15	c
16	a	17	c	18	c	19	c	20	b
21	c	22	d	23	c	24	b	25	a
26	b	27	a	28	c	29	c	30	d
31	d	32	c	33	c	34	a	35	c
36	b	37	c	38	d	39	b	40	b
41	d	42	c	43	a	44	a	45	a
46	c	47	c	48	a	49	d	50	d
51	c	52	d	53	c	54	d	55	a



56	d	57	b	58	c	59	c	60	d
61	b	62	c	63	d	64	c	65	c
66	c	67	b	68	a	69	c	70	b
71	a	72	a	73	c	74	c	75	c
76	b	77	a	78	d	79	b	80	a
81	c	82	b	83	d	84	b	85	d
86	b	87	c	88	c	89	b	90	b
91	a	92	a	93	e	94	d	95	b
96	b	97	c	98	c	99	a	100	d
101	a	102	b	103	a	104	b	105	c
106	b	107	a						

## NCERT Exemplar Questions

1	a	2	b	3	d	4	b	5	c
6	b	7	b	8	d				

## Critical Thinking Questions

1	d	2	d	3	c	4	b	5	a
6	c	7	a	8	a	9	b	10	a
11	d	12	d	13	a	14	d	15	a
16	b	17	b	18	e	19	c	20	b
21	b	22	a	23	d	24	c	25	a
26	a	27	a						

## Assertion and Reason

1	a	2	b	3	d	4	e	5	a
6	a	7	a	8	b	9	c	10	a
11	a	12	b	13	c	14	e	15	d
16	a	17	a	18	b	19	a	20	b
21	e	22	c	23	c	24	c	25	e
26	b	27	e	28	b	29	b	30	c
31	a	32	c	33	b	34	b	35	c
36	c	37	a	38	e	39	b	40	c
41	a	42	a	43	a	44	c	45	a
46	b	47	a	48	b	49	b		

# AS

## Answers and Solutions

## Root

2. (b) In plants growing in salty marshes some branches of tap root grow vertically upwards into the air from horizontally secondary roots. These roots are called pneumatophores

3. (c) In monocotyledonous plants the radicle dies immediately after germination of seeds and later these roots arise from any other portion (stem, leaves etc.) of the plant.
4. (c) Pneumatophores develop from horizontal roots. They bear a number of lenticels or pneumathodes. Exchange of gases occurs through these pores. e.g., *Rhizophora*.
5. (c) In epiphytic roots the outer covering is made up of spongy tissue, the velamen which absorbs moisture from air.
6. (b) Swollen adventitious roots of definite shape that occur in groups or fascicles, and arise from base of stem e.g. Dahlia.
7. (d) The swollen root is broad at the base and tapers gradually towards the apex.
8. (c) The root is nearly globular or spherical in shape. The basal portion of root is much swollen which suddenly tapers towards the apex giving a top shaped appearance, e.g., Turnip and Beet.
9. (d) The storage root is like a spindle, narrow towards both base and apex. It occurs in *Raphanus sativus*. The basal part of it is made of tap root.
10. (b) They are thin thread – like adventitious roots which often develop in groups. Fibrous roots provide better and firm anchorage to the plant, e.g., Grass.
11. (a) In some plants roots arise from lower nodes of stem and enter the soil to provide extra support. They behave as ropes of a tent. Such roots are called stilt or brace roots e.g., *Pandanus*
12. (c) These roots develop chlorophyll and become photosynthetic. They synthesize carbohydrates from carbon dioxide and water in presence of light, e.g., *Trapa*, *Tinospora*, *Taeniophyllum* and *podostemon*.
15. (c) It is adventitious because it is not formed from radicle.
17. (c) Plants belonging to sub-family papilionatae of family leguminosae (e.g., pea, gram etc.) bear nodule-like swellings, called root nodules. These nodules contain nitrogen fixing bacteria which fix atmospheric free nitrogen into ammonia.
21. (a) Some of the adventitious roots store food materials and become swollen. They arise singly and do not attain a definite shape, e.g., Sweet potato (*Ipomoea batata*).
28. (a) Pistia is hydrophyte where absorption of water by root is insignificant
29. (a) Velamen is a dead spongy tissue of empty cells. It absorbs water present on the surface of these roots
31. (d) Potato is modification of underground stem.
33. (d) These roots hang in the air and possess velamen or spongy tissue for absorbing moisture directly from atmosphere. The epiphytic roots are devoid of root hairs and root caps.
35. (d) Some aquatic and saprophytic angiosperms have no roots. In aquatic insectivorous plant-*Utricularia*, some leaves are finely dissected and carry on function of roots.

36. (d) Many roots can develop adventitious buds and take part in vegetative propagation, e.g., *Dahlia*, *Dalbergia*.
38. (d) They are laterally compressed horizontal roots which travel along the ground for some distance and provide extra mechanical support, e.g., *Ficus elastica*.
39. (d) Prop roots of Banyan tree helped it spread in an area of 200 acre in Indian Botanic Garden, Sibpur, Harwarh. This single Banyan tree had 1600 prop roots.
41. (c) Such roots are found in plants growing in mangroves or saline swamps near the sea shore.
42. (d) The region of fastest growth is behind the root tip. It is 4-8 mm long portion behind the tip. Here cells elongate rapidly due to vacuolisation.
43. (d) Prop or pillar or columnar roots : They are pillar-like roots which give extra mechanical support to heavy stem branches, e.g., Banyan tree.
44. (c) In *Pothos armatus*, *Acanthorhiza* and *Iriarteia*, some adventitious roots from the base of stem become hard, pointed and thorn like. Those roots are called root-thorns.
46. (d) Halophytes or mangroves like *Rhizophora*, *Raxburghiana*, *Sonneretia* etc., have pneumatophores and vivipary.
47. (b) Mango, ginger is a modification of adventitious roots. These roots become swollen at their tips due to accumulation of food.
48. (c) The roots where adventitious roots become swollen to store food. Fasciculated root is a type of storage root. e.g., *Dahlia*, *Ruellia*, *Asparagus* etc.
49. (d) Floating roots are white spongy and arise from node and stem store air. They help in floatation as well as in breathing also, e.g., *Jussiaea*.
52. (d) Many aquatic plants possess elongated loose cap like covering over their tips. They are called root pockets, e.g., Water Hyacinth (*Eichhornia*).
10. (d) Pedicel or floral stalks of *Artabotrys* produces a curved hook (which are modification of inflorescence axis) to help the plant in climbing.
11. (b) Phylloclades are modification of stem. These are green fleshy leaf like structure having nodes and internodes. Stem performs the function of photosynthesis.
12. (a) In bulb the stem is highly reduced and can be seen only as a disc like structure. On this disc are present numerous fleshy scaly leaves covering a central terminal bud. Both the disc and scaly leaves collectively are called bulb.
15. (a) Potato is (underground) stem because on the surface of potato many axillary buds or eyes are formed which are capable of growing into new plant.
16. (a) A special type of rhizome which grows vertically is called root stock, for example, *Alocasia indica* and *Musa paradisiaca* (Banana).
18. (a) *Opuntia* - Phylloclade
19. (a) Cabbage represents the largest apical bud. It is a vegetative bud and stores food.
20. (a) Onion - Bulb - underground stem, Ginger - Rhizome *Chlamydomonas* - Zoospore.
23. (b) Axillary buds developing at nodes/notch/eyes
24. (a) The entire bulb is covered by peripheral dry membranous leaf bases called tunics.
25. (d) Prickles are superficial (exogenous origin) outgrowths in any part of stem, branch, leaf and do not have vascular supply. Thorns are modified stem and differ from spines and prickles for example, *Bougainvillea*, *Carlissa* and *Duranta*.
26. (a) Sucker is a sub aerial branch that arises from the main stem. Initially it grows horizontally below the soil surface and later grow obliquely upward. They are shorter and stouter than the runners. e.g., *Meniha arvensis* and *Chrysanthemum*.
27. (c) In some weak stemmed plants, the axillary bud or terminal bud may modify to form tendrils which are specially called stem tendrils for e.g., *Passiflora*, *Atigonon*, *Vitis* etc.
30. (d) Root stock rhizome is oblique or vertical with tip almost reaching the soil surface.
32. (d) Ginger (*Zingiber officinale*) is an example of underground modifications of stem (rhizome) which has nodes and internodes.
33. (a) *Colocasia* is an example of corm.
34. (a) The axillary bud or terminal bud may modify to form tendrils which are specially called stem tendrils e.g., *Passiflora*.
36. (d) The rhizomes are perennial and vegetatively propagating structures and stores food materials and appear tuberous e.g., Ginger, Turmeric etc.
39. (c) Vegetative buds or floral buds modify into a swollen structure called bulbils or bulblets. It separates from the parent plant and gives rise to a new plant i.e., it is an vegetative reproduction, e.g., *Agave*, *Oxalis* etc.
42. (a) In onion food stored in leaf base is glucose.

### Stem

1. (b) Corm is an underground modification of main stem and stores food materials and becomes tuberous. Buds present externally corms give rise to new aerial shoots and new corms.
2. (a) Bulbils are fleshy vegetative buds which store food and take part in vegetative propagation. Bulbils of *Agave* germinate which still on inflorescence and thus show vivipary.
3. (b) Cladode are somewhat similar to phylloclade with the difference that cladode may be made up of only one internode. e.g., *Asparagus* (Satavar) or two internodes e.g., *Ruscus*
5. (d) Accessory buds borne at the leaf bases. They are two types : (i) Collateral buds present on the side of axillary bud, e.g., lilies (ii) Superposed buds present above the axillary bud e.g., *Aristolochia*.
7. (b) Thorns are actually modified axillary buds or terminal buds and they possess vascular supply.
9. (b) Sweet potato, Carrot - Edible root.  
Potato - Edible underground stem.

45. (a) Twiners are weak stemmed plants where the stem coils or twines around an upright support. Direction of coiling around the support is specific and genetically determined. The coiling is due to nutation.
46. (b) Multicellular hairs is the characteristic of stem.
47. (b) Potato is a modification of stem and sweet potato is a modification of root.
49. (d) They store food material in the basal portion and formed new corms e.g., *Colocasia*, *Alocasia*.
51. (b) Phylloclade is a modification of stem because the stem modifies into green fleshy leaf like structure having distinct nodes and internodes.

### Leaf

2. (c) Leaf is a thin flattened out growth of the plant arising from the node of the stem and having a bud in its axil.
5. (c) The leaves having even number of leaflets are termed as bipinnate, e.g., *Cassia*, *Tamarind* etc.
6. (d) In grasses and many monocots, the leaf base is broad and surrounds the stem as an envelope, such a leaf base is called sheathing leaf base. An additional outgrowth is present between leaf base and lamina. It is called ligule. e.g., Grasses.
7. (b) *Victoria regia* an aquatic plant with floating leaves. Which are 4 meters in radius and diameter 1.5-1.8 m. These are the largest leaves in plant kingdom.
8. (c) Parallel venation is the characteristic feature of monocotyledons. Exceptionally few dicots show parallel venation, e.g., *Calophyllum* and *Eryngium*.
9. (d) In this type, the primary rachis is divided once and produce secondary rachis. The leaflets develop on the secondary rachis. e.g., *Mimosa pudica* (Mimosoideae).
10. (b) The leaves are modified into slender wire and coiled structures called leaf tendrils. The tendril may be formed by entire leaf e.g., *Lathyrus aphaca* (Wildpea).
12. (b) Terminal leaflets modifies into tendril. e.g., *Lathyrus odoratus* (Sweet pea).
13. (b) The stipules are the small lateral appendages present on either side of the leaf base. Bud scales stipules are scaly which protect the leaf buds by surrounding them. e.g., *Ficus*, *Artocarpus*, *Banyan* etc.
14. (d) The unipinnate leaf with odd number of leaflets. The rachis is terminated by single unpaired leaflet. e.g., *Neem*, *Rose*, *Murraya*.
16. (a) The leaf having single undivided lamina is called the simple leaf. e.g., *Peepal*.
18. (c) When stipules are thin and modified into wire like structure these are known as tendrillar. These help in climbing of plants. e.g., *Smilax*.
20. (b) In Onion and garlic (underground bulb) scale leaves store food and become fleshy.
23. (d) In few plants the petioles are modified into tendrils and helps the plant climbing e.g., *Clematis* and *Tropaeolum*.
31. (a) A leaf is always borne at the node of stem.
32. (c) In *Utricularia* (Bladderwort) some of the leaves are modified to form small bladders (utricles) each of 1-3mm diameter.
33. (b) In this type of venation main veins divide into various branches and make a net-like structure in the lamina. It is found in most of the dicot plants.
35. (b) The underground stems having central axis, which grows and develops flower on top are called scape e.g., onion, garlic etc. Pedicel is the stalk of the flower. The broadened base of flower which lies at the tip of pedicel is called thalamus or torus.
36. (a) Circinate ptyxis is a folding or rolling from apex to base like spring of watch, e.g., fern leaves.
37. (d) Green, flattened petioles may be called winged petioles, e.g., *Citrus* and *Dionaea*.
38. (a) A pointed structure formed by the modification of entire leaf or part of a leaf is called a spine. Leaf or entire leaf may be modified into spines. e.g., *Opuntia* (axillary branches are modified into spines).
40. (c) The lamina is modified into broad pinkish pitcher of 1 to 10 inches in length.
42. (b) Because *Mangifera* (mango) is a dicot plant and reticulate venation found in dicots.
43. (a) It is the most familiar and wide spread type of compound leaf in which the rachis is elongated and bears two rows of simple or divided leaflets. The leaflets arranged alternately or in pairs along with the rachis.
44. (c) Multifoliate (Digitate) : A palmately compound leaf having five or more terminal leaflets, e.g., *Bombax malabarica*, *Cleome viscosa*, *Gynandropsis pentaphylla* etc.
45. (a) In parallel venation (striate venation), veins and veinlets run parallel to each other. Parallel venation is the characteristic feature of monocots.
50. (d) Membranous tubular stipules that ensheath the axillary bud and a part of internode is called ochraceous stipule. It is formed by the union of two stipules. e.g., *Polygonum* and *Rumex*.
52. (a) Only one leaf is found at each node. The leaves present at successive nodes alternate with each other. The arrangement is said to be alternate or spiral.
54. (c) Leaf base (Hypopodium) is the lower most part of the leaf meant for attachment. It acts as a leaf cushion.
55. (d) A pair of leaves at one node stands at right angle to the next upper or lower pair so that four vertical rows are formed on the stem. e.g., *Calotropis*, *Zinnia*, *Tulsi*, *Quisqualis*.
56. (c) In some plants leaves are modified into pointed spines which are known as leaf spines. These protect the plant from grazing animals and reduce the rate of transpiration in xerophytic plants.

### Inflorescence

5. (d) Capitulum (Head) : It is a characteristic of compositae (Asteraceae). Peduncle is flattened to form receptacle that bears centripetally arranged small sessile flowers called florets surrounded by involucre of bracts. e.g., *Marigold*, *Sunflower*.
7. (a) Flowers are arranged in acropetal succession, i.e., older flowers are towards the base and younger ones are towards the apex of the peduncle.

9. (d) Catkin (Amentum) is a compact pendent unisexual spike in which peduncle is thin and weak. e.g., *Morus* (Mulberry), *Populus* (Poplar), *Acalypha* (Cats tail), *Salix* (Willow), *Betula* (Birch).
12. (a) The florets are surrounded by an involucre of bracts.
14. (d) Hypanthodium is a special type of inflorescence formed by the condensation of main axis into a cup or flask-shaped fleshy receptacle
15. (c) Spadix is a modification of catkin spike in which the peduncle is thick and fleshy with upper part sterile (called appendix) and lower part bearing male, neuter and female unisexual flower surrounded by a large bract called spathe. e.g., *Musa paradisiaca*
16. (c) Spikelet is a compact spike having a few flowers borne on an axis called rachilla and surrounded by two bracts called glumes. e.g., Wheat, Oat, Grass. Each flower or floret has at its base a bract called lemma and a bracteole complex called palea.
18. (d) Flower occurs singly in the axil of a leaf, e.g., *China Rose*/ *Shoe flower* (*Hibiscus rosa - Sinensis*).
21. (b) It is a raceme of verticels or (whorls of flowers) borne on rectangular axis in the axils of opposite leaves. At each node there are two verticels. Each whorl consists of two clusters of 3-9 flowers e.g., *Ocimum* (Tulsi), *Salvia*, *Leucas*.
25. (d) Corymb (e.g., Cauliflower), catkin (Mulberry) and hypanthodium (Fig) are edible inflorescence
26. (c) A pendulous spike or spike-like inflorescence consisting of small unisexual flowers, e.g., *Morus alba* (Mulberry), *Salix* (Willow)
27. (b) More flowers are pollinated at a time, more fruits are produced
28. (a) Corymb of corymbs inflorescence found in Cauliflower. Edible Cauliflower (*Brassica oleracea* var. *Botrytis*) represents an undeveloped inflorescence.
29. (d) Involucre is whorl of bracts found in capitulum, umbel and cyathium
10. (a) Monoadelphous : Filaments of all the stamens are fused to form a tube around the gynoecium. Anthers are free. e.g., China rose.
11. (b) When stamens adnate or unite with petals. This condition is known as epipetalous. e.g., *Petunia*, *Datura*.
12. (e) Imperfect or unisexual or diclinous : A flower containing either stamens or pistils e.g., *Luffa*. These are of two types namely staminate which bear the stamens and pistillate bearing pistils.
13. (c) It is the third elongated internode between androecium and gynoecium e.g., *Capparis* and *Gynandropsis*.
14. (a) A plant bearing flowers of both sexes, i.e., Staminate and pistillate flowers, e.g., *Ricinus*, *Zea mays* (maize) and *Cucurbits*
19. (d) Descending imbricate aestivation in petals are found in *Papilionaceae* family.
23. (d) In Maize, flowers are unisexual but plant is monoecious.
24. (c) Foliaceous shape of sepals is present in *Mussaenda*
26. (b) The bracts found on the rachilla of spikelet are called glumes. They may be sterile glumes or fertile glumes (lemma), e.g., *Oryza sativa*.
27. (d) In many members of *Asteraceae* family, the sepals are modified into hairs called pappus. e.g., *Tridax*.
28. (c) Four free clawed petals arranged in the form of a cross, e.g., Mustard and Radish.
30. (b) Lodicules are modified tepals (Perianth). Perianth : 2, polyphyllous, small hyaline membranous antero-lateral scales called lodicules, hairy or smooth, whitish, inferior occur in *Triticum aestivum*.
31. (a) China rose, mustard, brinjal, potato, onion and tulip—total six plants have superior ovary.
32. (c) Gram, Arhar, Sunhemp, Moong, Pea and Lupin belongs to *Fabaceae* family that bears marginal placentation.
36. (b) Ray florets are always unisexual pistillate or neuter in heterogamous head inflorescence. In homogamous head, these are bisexual.
37. (c) The terminal receives portion of the style is called the stigma. It receives pollen grain during pollination.
39. (d) Perianth is the collective name of the nonessential floral organs if there is no distinction between sepals and petals
42. (a) Thalamus may show internodes, between various types of floral organs anthophore, androphore, gynophore. This evidence proves that flower is a modified shoot.
46. (b) *Rafflesia* is largest flower (1 meter).
48. (a) Hypogynous flower (hypo = below; gyny = ovary). Thalamus is conical or convex with gynoecium at top and other part below it, ovary is superior and other parts inferior. e.g., *Liliaceae*, *Malvaceae* and *Solanaceae*.
49. (b) Epigynous flower : Thalamus is hollowed out and fused with ovary. Other floral organs appear at the top of ovary. Gynoecium is inferior while other parts are superior
50. (c) Gynoecium consisting of two to many free carpels. Each carpel forms its own pistil, e.g., *Ranunculus*, *Lotus*

### Flower

1. (d) Hermaphrodite or perfect/bisexual / intersexual / androgynous / monoclinal : A flower having both the essential organs i.e., stamens and pistils. e.g., *Hibiscus*.
2. (a) The broadened base of flower which lies at the tip of pedicel is called torus or thalamus or receptacle.
3. (b) Synandrous : Stamens are fused in the region of both their filaments and anthers, e.g., *Cucurbita*, *Luffa*.
4. (a) Flower is highly modified and condensed shoot meant for sexual reproduction. It is characteristic of angiosperms
6. (c) The fused petals form a strap-shaped structure towards the upper end. A small hairy outgrowth, the ligule is present at the junction of the strap and the tube, e.g., ray florets of *Helianthus*
7. (c) Beauty of *Bougainvillea* flower is due to petaloid bract (Brightly coloured petal like bract).
8. (a) The flower may be described as complete if it bears all the floral whorls or floral parts

54. (b) The posterior petal is the innermost. It is being overlapped on the margins by lateral petals. The lateral petals are in turn overlapped by anterior petals, e.g., *Tamarindus*.
56. (c) Pappus : (Hairy or feathery sepals) sometimes sepals are modified into hairy structures which are useful in dispersal of seeds. e.g., Compositae / Marigold.
70. (b) Perianth is reduced to 2-3 boat shaped membranous lodicules. Lodicules found in family Gramineae (Poaceae).
71. (b) When stamens mature earlier than the stigma, it is known as protandry and the flowers are called protandrous e.g., Coriander, Jasmine, Sunflower etc.
72. (c) Filaments of a stamens are fused forming one bundle and the other bundle is represented by the filament of the tenth free stamen  $A_1 + (9)$ .
73. (b) Stamens inserted in two whorls : Outer whorl is opposite to petals, i.e., antipetalous. Whereas inner whorl is alternipetalous e.g., *Dianthus*.
77. (c) The plants of some species in which flowers are dimorphic. Thus facilitate cross pollination. Some of them possess a long style but short stamens and are known as pin-eyed while others have short style and long stamens. These are known as thrum-eyed. e.g., Primrose.
78. (a) *Cocos nucifera* belongs to family Arecaceae. In this family, flower containing either stamens or pistils. The floral parts are in multiples of three.
80. (d) The corolla of *Hibiscus* is polypetalous and twisted. *Hibiscus* is the member of family Malvaceae. Malvaceae comes under series thalamiflorae of class polypetalae. The petals are 5 and free. The aestivation of corolla is twisted in this family.
82. (d) Petals are 5, free, and twisted aestivation are found in china rose.
87. (c) *Datura*, mustard and tomato have actinomorphic flowers.
88. (a) Tomato — Berry, Orchid seed — no endosperm formation, Primrose — Free central placentation.
93. (b) Ovary is half inferior in perigynous flowers.
101. (d) Imbricate aestivation — *Cassia*, gulmohur.
104. (c) The stamens may be united into one bundle (monoadelphous), or two bundles (diadelphous) or into more than two bundles (polyadelphous).
105. (b) Radial symmetry is found in flowers like mustard, *Datura*, Chilli.
11. (b) Morphological dormancy-embryo is small & under developed.
12. (a) The fertilized ovule forms seed. The ovule increases greatly in size. The integuments dry up.
13. (c) Non-endospermic or Exalbuminous seed : Endosperm is completely consumed by the developing embryo and the mature seeds are without endosperm. The food is stored in cotyledons. e.g., Gram, pea, Bean etc.
14. (b) Vivipary is germination of seeds within fruit (in situ) while attached to the parent plant. Hypocotyl elongates and pushes the radicle but the seed and fruit hangs like *Damocles's sword* from the tree. It is found in mangroves (e.g., *Rhizophora*, *Sonneratia*).
15. (b) *Rhizophora* is a mangrove plant and vivipary is found in it.
16. (b) The mesocarp is thick, fleshy, juicy and edible part in *Mangifera* (Mango).
17. (a) Berry type of simple succulent fruits the pericarp divided into three layers — a thin delicate outer epicarp, a soft middle mesocarp and an inner layer known as endocarp. Both endocarp and mesocarp are fleshy. The slippery, oval, orange, coloured seeds are attached by stalks to the placenta. e.g., Tomato, Brinjal.
18. (c) Caryopsis : It is very small dry and one seeded fruit which develops from a superior monocarpellary ovary. Here the pericarp is closely fused with seed coat. It is the characteristic of family gramineae. e.g., Wheat, Maize.
19. (a) The aggregate fruits are formed from polycarpellary, apocarpous ovary of a single flower. e.g., *Mitchellia*, *Rubus*, *Annona*.
20. (c) Caryopsis is one-seeded dry indehiscent fruit developed from a monocarpellary, unilocular and superior ovary. e.g., Wheat, Maize, Paddy.
21. (d) Hesperidium is many chambered and many seeded fleshy fruit developed from multicarpellary, syncarpous and superior ovary. The epicarp is leathery and glandular, mesocarp is thin and smooth, e.g., Lemons and oranges.
25. (c) Lomentum is a type of fruit. It is a dry many seeded fruit which develops from a monocarpellary, superior, unilocular ovary with marginal placentation.
28. (c) The fruit of *Datura* is septicidal capsule but its dehiscence is of septifragal nature in which placenta remains attached in the centre of undivided fruit and pericarp's segment becomes separated.
29. (d) The structure present within the seed coat is called kernel. Endosperm, embryo and cotyledon are the part of kernel.
30. (b) Mechanical scarification (Rupturing of seed coats) by filing, chipping or machine threshing.
31. (d) Castor is an endospermic (Albuminous seed). In albuminous seeds, embryo not consumed all endosperm. So it persists in the mature seed. In these seeds food stored in endosperm. In castor, the cotyledons come above the surface of the soil into the air and light due to the rapid growth and elongation of the hypocotyls. The cotyledons turn green and finally dry up and fall off and seedling becomes an independent plant. It is a type of epigeal germination.

### Seeds and Fruits

1. (d) The orchids seeds (0.004 gm) are smallest in Angiosperms. These are small, dry and light and can be carried by wind to over 1000 km.
3. (b) Seed is a fertilized and ripened ovule (mature integumented megasporangium) found in phanerogams (spermatophytes).
4. (a) The main body of the ovule is covered with one or two envelopes called integuments.
9. (a) Viability of seeds : Ability of seed to have power of germination over a period of time is called viability. It is maximum in *Lotus* (*Nelumbo nucifera*) i.e., 400-2000 years.

32. (b) Pepo is a special type of berry, the epicarp and thalamus form the outer ring of the fruit. The mesocarp, endocarp and placenta are fused to form pulp which is edible. e.g., Members of cucurbitaceae family.
34. (a) Water is of primary importance in germination. When seed protoplasm absorb the water, seed resumes vigorous physiological activities. The embryo bursts through the seed coats.  $O_2$  is also necessary for respiration and other physiological activities.
36. (b) Simple fruits develop from monocarpellary ovary or multicarpellary syncarpous ovary.
37. (a) The pericarp of drupe consists of a thin epicarp (forms the skin), a fleshy mesocarp (forms the edible part) and hard and stony endocarp e.g., *Cocos nucifera*.
38. (d) Seeds of some species are edible e.g., *Pinus gerardiana* (chilgoza pine). This plant is common in dry valley North West Himalayas and Kashmir.
39. (c) Sorosis develop from spike, spadix or catkin inflorescence. Bracts, perianth and seed become simple and are used for eating in pine apple and mulberry.
47. (d) Fig- developed by hypanthodium inflorescence.  
pineapple- developed by spike inflorescence.  
Mulberry-developed by catkin inflorescence.
52. (a) Hesperidium is a modification of berry. It develops from a polycarpellary syncarpous, superior ovary with many seeds.
62. (a) Mango – seeded fruit  
Sterile stamen – staminode  
Seeds in grasses – endospermic.
65. (b) Tomato – Berry, Wheat – Caryopsis, Pea – Legume.
74. (b) Seed of garden pea is ex-albuminous or non endospermic.
8. (a) The fruit and seeds surface possesses sticky glands for attaching to the body of animals, e.g., *Plumbago*, *Boerhaavia*, *Cleome viscosa*.
9. (b) Seed bear hair all around.
10. (b) The fruit of Asteraceae often possess pappus (persistent hairy calyx) which functions as a parachute for dispersal.
11. (c) The surface of many fruits is covered with hooks (e.g., *Xanthium*, *Urena*), spines (e.g., *Tribulus*) bunch of stiff hair or barbs (e.g., *Aristida*) by means of which they adhere to the body of animals or clothes of human beings and they are carried unwarily from one place to another.
12. (d) Fruits of *Bignonia* are dispersed by birds.
13. (b) Sticky seeds of *Rafflesia* are dispersed by elephants.
14. (d) Human beings and birds are active and useful agent in distributing these fruits.
15. (c) The seeds of *Moringa* (Drumstick), *Oroxylum*, *Cinchona* and *Pinus* are winged. The dispersal of seeds by wind is called anemochory.
16. (d) Seed and fruits possess air cavities to keep them a float on water e.g., spongy seed coat of water lily (*Nymphaea*), aril in the seed of water lily help seeds to float in water by giving buoyancy and fleshy, aril or a kind of third integument is edible part of *Litchi*.
17. (b) In many fruits, testa is modified to form wings as in *Cinchona*, *Oroxylum*, *Moringa*, *Sweetenia* and *Lagerstroemia*.
18. (c) Censer mechanism occurs when seeds are dispersed from small pores in the fruits by swinging in air. e.g., *Papaveraceae* (Poppy), *Aristolochia* and *Aconitum*.

### Dispersal of fruits and seeds

1. (a) In legumes the dry pods split open into two valves which undergo spiral twisting to throw the seeds e.g., *Pea*, *Abrus*.
3. (b) One or more tufts of hairs attached on seeds constitute coma e.g., *Calotropis*. *Calotropis* is insect pollinated but dispersed by wind. Its seeds are plumed (hairy). It has pollinia containing anther to be carried by insects.
4. (b) The fruits of *Clematis* and *Naravella* possess persistent hairy styles which help in floating in air.
5. (d) Autochory (Dispersal by explosion) is self dispersal of the seeds which occurs when the fruit splits up at maturity. Such fruits open with force and scatter the seeds in all directions.
6. (a) In *Ruellia* and *Justicia* (Acanthaceae) the exposed seeds are thrown away with the help of Jaculators (Jaculator mechanism). Jaculator is a curved hook at the base of seed which open with jerk to throw seeds.
7. (d) In members of the family Asteraceae, sepals are modified into tufts of hairs called pappus. The pappus is persistent and hence found attached to even small, single seeded fruits. It acts like a parachute that allows the wind to carry them to great distances.
8. (a) The fruit and seeds surface possesses sticky glands for attaching to the body of animals, e.g., *Plumbago*, *Boerhaavia*, *Cleome viscosa*.
9. (b) Seed bear hair all around.
10. (b) The fruit of Asteraceae often possess pappus (persistent hairy calyx) which functions as a parachute for dispersal.
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### Taxonomy of Angiospermic plants

1. (b) Floral formula of *Allium cepa* (onion).
2. (a) Fabaceae commonly called Legume family; 4<sup>th</sup> largest and 2<sup>nd</sup> most valuable family. It has a 600 genera.  
Poaceae commonly called cereal / grass family; 3<sup>rd</sup> largest family but Indian flora, they constitute the largest family (620 genera).
3. (d) Family cucurbitaceae belongs series calyciflorae (sepals are fused or free, ovary is usually inferior) and order passiflorales.
4. (c) Touch me not (*Mimosa pudica*) belongs to sub family mimosoideae. It comes under Papilionatae (fabaceae).
5. (b) Liliaceae commonly called lily family; belong to monocotyledons. Perianth (calyx and corolla undifferentiated), biserial (2- whorled) and petaloid.
8. (c) Compositae (Asteraceae) is the largest family of plant kingdom, represented by 950 genera and 20000 species, plants mostly herbs stem with latex / oil ducts and most evolved and advanced among dicot.
9. (d) All stamens of a flower fuse by their filaments to form a single staminal tube e.g., family Malvaceae (*Hibiscus*).
11. (a) In family Compositae (Asteraceae) 2 stamens, epipetalous, syngenesious, dithecous, bilobed, introse, filament free.

12. (c) *Cajanus cajan* (Pigeon pea / Red gram / Arhar) belong to family Leguminosae (fabaceae).
14. (b) Poaceae (Gramineae) is the 3<sup>rd</sup> largest but economically most valuable family as it provides cereals and millets.
16. (a) *Carthamus tinctorius* (safflower) belongs to family Asteraceae. It yield Safflower / Kusum oil containing 73% PUFA (Poly unsaturated fatty acids) its good for heart patients.
17. (c) Cauliflower is an apical bud belonging to family Cruciferae (Brassicaceae).
18. (c) Commonly called mustard family : Plants predominantly herbs and sulphur smelling being rich in sulphur rich glucosides like sinigrin and hence are pungent.
20. (b) Family Asteraceae belongs to subclass – Gamopetalae (The petals are fused, stamens are epipetalous, carpel may be syncarpous or apocarpous) and series – inferae (ovary is inferior and stamen usually equal to petal lobes).
21. (c) Axile placentation : In a multicarpellary syncarpous gynoecium the fusing margins grow inwards to meet in the center of the ovary to form an axis thus making the ovary multilocular. The ovules are borne on the central axis. e.g., Family Solanaceae and Liliaceae.
22. (d) In Fabaceous (Papilionaceous) corolla has petals 5, polypetalous, the posterior petal is largest (standard) and two laterals are wing and inner two anterior are fused to form a boat shaped structure called keel or carina.
24. (b) *Eleusine coracana* (Finger millet/Ragi) is hardest millet and its grains are free from pericarp.
26. (b) Placentation parietal but bilocular due to false septum or replum in *Brassica campestris*.
27. (a) Anterior petals are fused to form a boat-shaped structure called keel or carina.
29. (c) Sepals 4, polysepalous, arranged in two whorls, outer of antero-posterior sepals and inner of lateral sepals, lateral sepals generally saccate or pouched at the base, green or petaloid, inferior.
31. (d) Commonly called sunflower, largest family of plant kingdom, represented by 950 genera and 20000 species.
33. (c) *Allium sativum* (garlic), *Allium cepa* (onion) and *Aloe vera* belongs to family Liliaceae.
34. (a) *Allium cepa* belongs to monocot family – Liliaceae, when remaining three are dicot.
36. (b) Corm of *Colchicum autumnale* is source of an alkaloid colchicine used to induce polyploidy.
37. (c) *Parthenium hysterophorus* (carrot grass / congress grass), a most nasty weed, came into India from USA during congress rule in 1950's along with wheat.
38. (d) Epipetalous (Epiphyllous) : Stamens adnate with tepals. Syngenesious (synantherous) : Anthers fused, filaments free in a flower.
39. (b) Cereals are one seeded fruit called caryopsis. They are rich in carbohydrate, poor in lysine and tryptophan. Cereals comes under family Poaceae
41. (d) *Cajanus cajan* is leguminous plant belongs to family Leguminosae. It has root nodules by which they can fix atmospheric nitrogen.
43. (a) All pulses belong to family Fabaceae. This family is known for protein rich pulses.
46. (c) Flower of family Solanaceae is bracteate or ebracteate, pedicellate, complete, hermaphrodite, actinomorphic, pentamerous, hypogynous.
47. (c) Bracteoles modify into palea.
56. (d) Petals 4, polypetalous, arranged in one whorl and alternate with sepals, often with long claws and spread out in the form of a Greek cross. This arrangement of petals is known as cruciform arrangement.
59. (c) In this type of placentation, the ovary is simple, unilocular and the ovules are arranged along the margin of the unilocular ovary. The placenta develops along the ventral suture of the ovary. e.g., Pea, Gram.
61. (b) Pea- Diadelphous
62. (c) Under- developed, sterile stamens non-functional that do not produce pollens, e.g., *Salvia*, *Cassia*.
63. (d) Parietal Ex. – Mustard  
Free central Ex. – Primula and Dianthus  
Marginal Ex. – Pea  
Axile Ex. – Tomato, lemon, Chinrose
64. (c) Leguminosae family possess marginal and Cruciferae possess parietal placentation.
65. (c) In Leguminosae ovary is superior.
78. (d) Tetradyamous condition of stamens is found in mustard (*Brassica campestris*) plant of family Cruciferae (Brassicaceae). In tetradyamous condition four stamens remain long and two short.
79. (b) In diadelphous condition, stamens are arranged in two bundles. Diadelphous stamens are the characteristic features of family Fabaceae.
83. (d) *Brassica nigra* (Black mustard) comes under Cruciferae (Brassicaceae) family.
84. (b) There are six free stamens, inner four are large and outer two are small, e.g., Mustard, *Iberis* (Cruciferae family).
86. (b) In solanaceae bilocular, axile placentation, ovary obliquely placed due to rotation of posterior ovary towards right side and anterior carpel to left side by 45°. Placentae highly swollen, ovules are maximum per locule in this family.
87. (c) On the basis of characters of corolla (symmetry) of flower, type of petals and their fusion and aestivation) and androecium (No. of arrangement), this family is divided into 3 sub families
88. (c) The bacteria (*Rhizobium* spp.) associated with the root nodules of legumes fix atmospheric nitrogen.

### Critical Thinking Questions

1. (d) In plants like *Arceuthobium*, *Rafflesia*, *Sapria*, *Podostemon*, shoot develops for flowering otherwise roots form main part of the plant.
5. (a) Aggregate of small berries, e.g., Custard apple. Apical parts of berries fuse with each other to form a common rind.
6. (c) Onion - Bulb - Underground stem-Imbricate aestivation- Axile placentation - Member of Liliaceae.



7. (a) Cladodes (Cladophylls) : They are green photosynthetic stems of limited growth (generally one internode only) with leaves reduced to scales or modified into spines, e.g., *Ruscus*, *Asparagus*.
10. (a) Some plants never open to ensure complete self-pollination. This condition is called cleistogamy e.g., *Commelina bengalensis*, *Oxalis*, *Viola*, etc. The cleistogamous flower are bisexual small, inconspicuous, colourless and do not secrete nectar.
12. (d) Bulbils are fleshy buds produced in the axil of foliage leaves in place of axillary buds. In century plant (*Agave* sp.) the floral buds are modified into bulbils which grow into new plants when shed from the mother plant.
15. (a) Descending imbricate or Vexillary aestivation : The posterior large standard petals overlaps the lateral petals called wings or alae on the margins while the lateral wings overlap the anterior keel or carinal petals, e.g., Pea, Gram.
16. (b) Apocarpous : Gynoecium consisting of two to many free carpels. Each carpel forms its own pistil, e.g., *Ranunculus*.
17. (b) Mother axis : The shoot on which the flower is borne is called mother axis. The side of the mother axis is always posterior while the side of the bract is anterior
19. (c) Stylopodium : Swollen base of style in Umbelliferae (Apiaceae).
20. (b) In Malvaceae/cotton anther single-lobed, 2 chambered (bisporangiate), connective is absent. Filament is attached to the base of the anther.
21. (b) Hairy styles : The fruits of *Clematis* possess persistent hairy styles which help in floating in air.
22. (a) In several species, of Australian *Acacia* (e.g., *A. melanoxylon*, *A. auriculiformis*), the petiole and part of rachis expands to form phyllode. Phyllodes are vertical, have fewer stomata and therefore, lose less water in transpiration.
23. (d) Stigma feathery or papillate. Silken threads of Maize are very long stigmas but some authors regard them as long styles bearing equally long stigmas in the apical region.
24. (c) Diadelphous : The filaments are united forming two bundles, e.g., in *Lathyrus* (sweet pea), *Pisum* (edible pea) there are 10 stamens; filaments of 9 stamens are fused forming one bundle and the other bundle is represented by the filament of the tenth free stamen ( $A_1 + (9)$ ).
25. (a) Composite fruits : These fruits are developed from the complete inflorescence and are known as infructescence. These are of 2 types :  
(1) Sorosis                      (2) Syconus or Syconium
26. (a) Tetradynamous : There are six free stamens, inner four are large and outer two are small, e.g., *Brassica* (mustard).
2. (b) The root cap protects the root meristem from friction of the soil particles. In this process, its outer cells are continuously peeled off and replaced by new cells formed from root meristem. In floating aquatic plants the root apices possess finger glove-like coverings called root pockets instead of root cap.
3. (d) Root pockets are found in floating aquatic plants. They act as balancers. They are structurally similar to root caps but differ from them in the fact that the damaged root pockets are not regenerated
4. (e) Root hair zone is 1–6 cm in length. The root hairs increase the exposed surface of the root for absorption of water and minerals.
5. (a) Syconous fruit develops from hypanthodium inflorescence in which 3 types of flowers are found i.e., male, female and sterile gall flowers. Male flowers and gall flowers cannot develop into fruits. So in syconous type of fruit, the achenes formed are fewer than the total number of flowers in the inflorescence.
6. (a) *G. herbaceum* belongs to family-Malvaceae. Taxonomic hierarchy is the system by which various taxonomic categories are arranged in a proper descending order. The ascending taxonomic hierarchy shows that a taxon belongs to a number of taxa and its placement in progressively higher groups
7. (e) Deep feeder tap root system has an elongated tap root which penetrates the deeper layers of the soil. It is mostly met in trees. Deep feeder tap root is also called racemose tap root system. In surface feeders the tap root does not elongate very much. The secondary roots spread to a greater extent. Such a system is also named as cymose tap root system.
8. (b) Coconut require the hot and wet climate hence it is grown in coastal areas. It is widely grown in coastal and deltic regions of tropical and subtropical countries. Coconut fruit show hydrochory i.e., the dispersal takes place through water medium. Being the habitat of coastal area the fruit is so adapted that it can float and dispersed over thousand of kilometers before losing viability.
9. (c) The fleshy roots are thickened like the palm of human hand. They similarly possess finger like outgrowth, e.g., *Orchis*. They are Palmate roots. Fasciculated fleshy roots are the swollen roots or root tubers occurring in clusters.
10. (a) Moniliform or beaded roots are swollen at regular intervals like beads of a necklace. Hence the roots has the appearance of necklace. Such roots are found in *Discorea*, *Momordica charauter* etc.
11. (a) Assimilatory roots are green roots (as they contain chlorophyll) which are capable of photosynthesis. e.g., *Taeniophyllum*, is a leafless epiphytic orchid with thick flattened photosynthetic roots.
12. (b) Epiphytes live on the surface of other plants for shelter and space only, hence also called space parasites. Epiphytic roots possess a covering of dead spongy tissue known as velamen. With the help of velamen, they are able to absorb water from moist atmosphere, dew and rain.

### Assertion and Reason

1. (e) Root is typically a non green underground cylindrical structure forming the descending axis of the plant which gives rise to endogenous branches and does not possess nodes, leaves or buds. Presence of nodes and internode is the characteristic feature of stems.



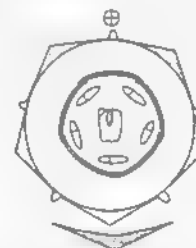
13. (c) Albuminous seeds are those where endosperm is present, as in maize and castor bean. The endosperm persists in their seeds. In exalbuminous seeds, the endosperm is completely absorbed by the growing embryo and the food reserve gets stored in the cotyledons.
14. (e) In syngenesious condition when the stamens are united by their anthers only, the filaments remaining free. In synandrous, stamens are fused by both these filaments as well as anthers.
15. (d) Stem is usually the above-ground erect ascending part of the plant body that develops from the plumule, grows by means of a terminal bud and shows distinction of nodes and internodes. The nodes bear leaves having axillary buds
16. (a) A bud is a condensed immature or embryonic shoot having a growing point surrounded by closely placed immature leaves. The largest bud is cabbage.  
According to their nature, buds can be vegetative, reproductive and mixed
17. (a) In cymose branching the growth of the main stem is definite, that is the terminal bud does not continue to grow, but lower down, the main stem produces one or more lateral branches which grow more vigorously than the terminal one. In some plants the terminal bud gets modified into a flower, tendril, thorn etc
18. (b) Ginger is horizontal in position and generally branched and producing aerial leaves or shoots aboveground and adventitious roots on lower side in favourable season. Thus shoot growth is not effected by gravity.
19. (a) Many fruits are provided with hooks, barbs, spines, bristles, stiff hairs etc., on their surface by means of which they adhere to the body of woolly animals as well as to the clothing of mankind and are often carried by them to distant places. The animals are forced to carry such fruits and seeds, e.g., forced zoochory.
20. (b) Human travellers have always taken plants from one area to another. Potato was brought from New World by the Portuguese. Many economically important crops and plants such as maize, tobacco, groundnut, chillies, tea, cabbage, cauliflower, rubber etc. are dispersed by man, as they have been introduced to new areas from their original home. However, many weeds are also dispersed alongwith useful plants.
21. (e) The pericarp of drupe is differentiated into epicarp, mesocarp and endocarp. Endocarp is stony. Hence drupes are also called stone fruits. Coconut called fibrous drupe due to fibrous mesocarp, possesses edible endosperm. Among drupes, the mango has edible mesocarp, cherry, peach, plum and *Zizyphus* have edible epicarp and mesocarp.
22. (c) The pedicels or floral stalks of *Artabotrys* are modified into stiff curved thorns or hooks for helping in climbing. In *Antigonon* the flowers occur in bunches in the axils of scale leave on the floral shoot. The upper floral buds develop into tendrils instead of forming flowers.
23. (c) Prickles are superficial outgrowths of stem or leaves which do not possess a vascular cylinder. They can be easily pulled off. Bristles are stiff hair which become thickened due to deposition of silica or calcium carbonate
24. (c) Caryopsis is a superior achenial fruit where testa and pericarp are inseparably fused, e.g., wheat, maize etc. Achenial fruits are single seeded indehiscent dry and simple fruits. The pericarp is dry and undifferentiated. The pericarp of wheat is thus dry and it is fused with testa
25. (e) Leaf is a green, dissimilar exogenous lateral outgrowth which is borne on the node of a stem or its branch and is specialised to perform photosynthesis. All the green leaves of a plant are collectively called foliage. Phyllotaxy is the arrangement of leaves on the stem or its branches
26. (b) Achenial fruits are single seeded indehiscent dry and simple fruits. The pericarp is dry and undifferentiated. Capsular fruits are many seeded dry and simple fruits in which the pericarp splits open to expose the seeds.
27. (e) In spiral arrangement, each node bears a leaf and the leaves of the adjacent nodes roughly lie towards the opposite sides. In opposite arrangement, two leaves are borne on the opposite sides of a single node. When three or more leaves develop on the nodes, they form whorled arrangement
28. (b) A leaf having a single or undivided lamina is called simple leaf. The lamina can have different types of incisions, which may reach upto half (-fid), more than half (-partite) or near the base or midrib (-sect). Depending upon the pinnate or palmate venation, the incisions are known as pinnatifid, palmatifid, pinnatipartite, palmatipartite, pinnatisect and palmatisect.
29. (b) The palmate compound leaf is one in which the petiole bears leaflets at the tip like the fingers of the palm. *Citrus* is actually a palmate compound leaf where the two lateral leaflets have been suppressed and only the central leaflet is functional. Such a palmate compound leaf, with one functional leaflet is called unifoliate compound leaf.
30. (c) The petiole, rachis and the stalks of the leaflets in *Clematis* are sensitive to contact and can coil around the support to help the plant in climbing. In whole leaf tendril, the whole leaf is modified into a tendril for climbing. The leaf apices of *Gloriosa superba* are greatly elongated to function like the tendrils.
31. (e) Prickles are defensive organs of plants but prickles being usually curved are commonly used for climbing. They are superficial outgrowths of stem or leaves which do not possess a vascular cylinder
32. (c) Samara is an achenial fruit having winged pericarp, e.g. *Ulmus* (Elm). Achenial fruits are single seeded indehiscent dry and simple fruits. Achenial winged fruits are called samaroid if the wings develop from places other than pericarp, e.g., sepals in *Shorea*.
33. (b) Phyllodes do not bear leaves, branches, flowers, etc. In *Parkinsonia aculeata*, the rachis ends in a spine. Rachis branches are elongated, flattened and green to function as phyllodes. They bear small leaflets which fall off very easily

34. (b) Persistent sepals are called accrescent if they grow along with the fruit (i.e., *Physalis*). They (persistent sepals) are marcescent when they assume a dried up form before being shed, i.e., *Guava*.
35. (c) A flower is regarded as complete if it has all the four floral whorls, i.e., calyx, corolla, androecium and gynoecium. If any of these whorl is missing the flower is described as incomplete. An incomplete flower can either be perfect, having male as well as female sex organs or imperfect with either of the sexes missing. When both the essential organs are absent, the flower is spoken as neuter.
36. (c) Hypanthodium has a flask – shaped fleshy receptacle which possesses a narrow canal and a terminal pore at one end. Internally the receptacle bears male flowers towards the pole and female flowers towards the base. Sterile, neuter or gall flowers occur in between the two groups.
37. (a) Heterophylly is met within many aquatic plants, particularly in those growing in shallow running water. Here the floating or aerial leaves and the submerged leaves are of different kinds; the former are generally broad, more or less fully expanded and undivided or merely lobed; while the latter are narrow, ribbon-shaped, linear or much dissected. Examples are *Sagittaria*, *Ranunculus aquatilis*, *Limnophila heterophylla*.
38. (e) In caducous, leaves fall down soon after their appearance, e.g., *Opuntia*. In deciduous almost all leaves fall off almost simultaneously at the end of growing season. The phenomenon is called leaf fall, e.g., Mulberry, Poplar. In *Euphorbia royleana* the leaves are drought deciduous.
39. (b) When the leaf is more or less cylindrical and directed upwards or downwards, as in onion such leaf is called centric leaf. A centric leaf is equally illuminated on all sides and, therefore, it is evenly green. Centric leaves of onion is aerial. It is underground scale leaves of bulb which store food.
40. (c) China-rose has free lateral stipules and rose bears adnate stipules. Free lateral stipules are free stipules, usually small and green in colour, borne on the two sides of the leaf-base. Adnate stipules are two lateral stipules that grow along the petiole upto a certain height, adhering to it and making it somewhat winged in appearance.
41. (a) Cymose inflorescence is the name of determinate or definite inflorescence in which the tip of the main axis terminates in a flower and further growth continues by one more lateral branches which also behave like the main axis.  
Verticillaster is a special form of cymose inflorescence. The first axis ends in a flower, it bears two lateral branches, each ending in a flower, succeeding lateral branches are produced in an alternating manner.
42. (a) Leaves of a number of plants develop or possess adventitious buds for vegetative propagation, e.g., *Bryophyllum*. *Begonia* leaf develops buds only when the leaf is injured or detached.
43. (a) Walking ferns (e.g., *Adiantum caudatum*) reproduce vegetatively by their leaf-tips. Leaves bow down to the ground, their tip strikes roots and forms a bud which grows into a new plant.
44. (c) In corymb, the main axis is shortened and lower flowers have much longer stalks or pedicels than the upper ones so that all the flowers are brought more or less to the same level. Corymb inflorescence is found in *Cassia* sp.
45. (a) The spadix contains a large green or coloured bract called spathe. For example, in banana and aroids, the brightly coloured spathe attracts insects to facilitate pollination.
46. (b) In racemose head, the main axis or receptacle is suppressed, becoming almost flat. It bears a mass of small sessile flowers (florets) on its surface, with one or more whorls of bracts at the base forming an involucre. The florets are arranged in a centripetal fashion, i.e., younger towards the centre and older towards the periphery. The advantages of this kind of inflorescence are that the head as a whole becomes more showy and attractive and the florets being close together, one or a few insects can pollinate most of them within a short time.
47. (e) In cymose inflorescence, the main axis ends in a flower and similarly the lateral axis also ends in a flower. Thus the growth of each axis is checked. In cymose inflorescence, the terminal flower is always older and opens earlier than the lateral ones, i.e., the order of opening of flowers is centrifugal.
48. (b) Compound umbel is branched umbel, where several small or daughter umbels arise from a common point in an umbellate fashion. A whorl of bracts, called involucre is present at the base of the daughter umbels are called involucels.
49. (b) Cyathium is a special kind of inflorescence found in *Euphorbia*, i.e., *Poinsettia* and *Euphorbia*.  
In cyathium there is a cup – shaped involucre, often provided with nectar – secreting glands. The involucre encloses a single female flower in the centre, seated on a comparatively long stalk and a number of male flowers around this, seated on short slender stalks.

## Morphology of Flowering Plants

## Self Evaluation Test

- A plant which lives for a few days is called [Odisha JEE 2004]  
(a) Annual (b) Perennial  
(c) Biennial (d) Ephemeral
- Perianth in the spikelet of jawar is represented by [MHCET 2004]  
(a) Lodicules (b) Sepals and petals  
(c) Glumes (d) Lemma and palea
- Heterostyly is show by [MHCET 2004]  
(a) *Primula* (b) *Mirabilis*  
(c) *Helianthus* (d) China rose
- Which is odd one [MHCET 2004]  
(a) China rose (b) Maize  
(c) Mango (d) Sunflower
- Bicarpellary syncarpous gynoecium, parietal placentation, tetradynamous stamens and siliqua fruit are characteristic features of family [CBSE PMT 1992; APMEE 1993; RPMT 1994, 95; CPMT 1998]  
(a) Cucurbitaceae (b) Cruciferae  
(c) Compositae (d) Solanaceae
- What name has been assigned to the genus produced by a cross between cabbage and radish [BHU 2004]  
(a) *Secale* (b) *Bursa pastoris*  
(c) *Lysogenicophyll* (d) *Raphano brassica*
- The condition where filaments and anthers are fused throughout the entire length is [Odisha JEE 2004]  
(a) Synandrous (b) Gynadrous  
(c) Protandrous (d) Syngenesius
- In a seed of maize, scutellum is considered as cotyledon because it [AIIEE Pharmacy 2004]  
(a) Protects the embryo  
(b) Contains food for the embryo  
(c) Absorbs food materials and supplies them to the embryo  
(d) Converts itself into a monocot leaf
- Ephemerals are drought [Odisha JEE 2009]  
(a) Loving (b) Enduring  
(c) Escaping (d) Resistant
- In a monoecious plant [DUMET 2009]  
(a) Male and female sex organs are on different individuals  
(b) Male and female gametes are of two morphologically distinct types  
(c) Male and female sex organs are on the same individual  
(d) All the stamens are fused to form one unit.
- Viral infection is usually absent in [MP PMT 2009]  
(a) Phloem cells (b) Xylem cells  
(c) Pith cells (d) Apical meristem
- Transparent hairs on catkins and caterpillars function to [Odisha JEE 2008]  
(a) Trap heat (b) Trap moisture  
(c) Reflect light (d) Drink water
- In coconut fruit, the hard shell is [MP PMT 2010]  
(a) Endocarp  
(b) Fused structure of mesocarp and endocarp  
(c) Fused structure of epicarp and mesocarp  
(d) Epicarp
- Ginger multiplies vegetatively by [DPMT 2004]  
(a) Tuber (b) Corn  
(c) Sucker (d) Rhizome
- The floral formula for Malvaceae is [RPMT 1997]  
(a)  $\oplus \overset{\circ}{\underset{+}{\text{Epl}}}_{(3-7)} K_{(5)} \overset{\circ}{\underset{+}{\text{C}}}_{(5)} \overset{\circ}{\underset{+}{\text{A}}}_{(1)} \underline{\overset{\circ}{\underset{+}{\text{G}}}_{(5)}}$   
(b)  $\oplus \overset{\circ}{\underset{+}{\text{Epl}}}_{(3-7)} K_{(5)} \overset{\circ}{\underset{+}{\text{C}}}_{(5)} \overset{\circ}{\underset{+}{\text{A}}}_{(5)} \underline{\overset{\circ}{\underset{+}{\text{G}}}_{(5)}}$   
(c)  $\oplus \overset{\circ}{\underset{+}{\text{Epl}}}_{(3-7)} K_{(5)} \overset{\circ}{\underset{+}{\text{C}}}_{(5)} \overset{\circ}{\underset{+}{\text{A}}}_{(1)} \underline{\overset{\circ}{\underset{+}{\text{G}}}_{(5)}}$   
(d)  $\oplus \overset{\circ}{\underset{+}{\text{Epl}}}_{(3-7)} K_{(5)} \overset{\circ}{\underset{+}{\text{C}}}_{(5)} \overset{\circ}{\underset{+}{\text{A}}}_{(1)} \underline{\overset{\circ}{\underset{+}{\text{G}}}_{(3-\infty)}}$
- A monocot showing reticulate venation is [APMEE 1995]  
(a) *Bombusa* (b) *Smilax*  
(c) *Callophyllum* (d) *Ginkgo*
- Chief feature of family Brassicaceae/Cruciferae is presence of [APMEE 1994; BHU 2002]  
(a) Latex (b) Pectin  
(c) Alkaloids (d) Myrosin enzyme
- In *Gloriosa* (Glory lily) the tendril is formed from  
(a) Stipule (b) Leaf apex  
(c) Axillary bud (d) Leaf
- Select the wrong statement [NCERT; Kerala PMT 2007]  
(a) Persistent calyx is seen in *Solanaceae*  
(b) Flowers are hypogynous in *Asteraceae*  
(c) Santonin is obtained from *Artemisia*  
(d) In *poaceae*, perianth is represented by membranous scales called lodicules  
(e) Parietal placentation is characteristic of *Brassicaceae*
- Largest inflorescence is found in  
(a) *Acalypha* (b) *Populus*  
(c) *Amorphophallus* (d) Cabbage
- Choose the correct description depicted by floral diagram [NCERT; KCET 2002]



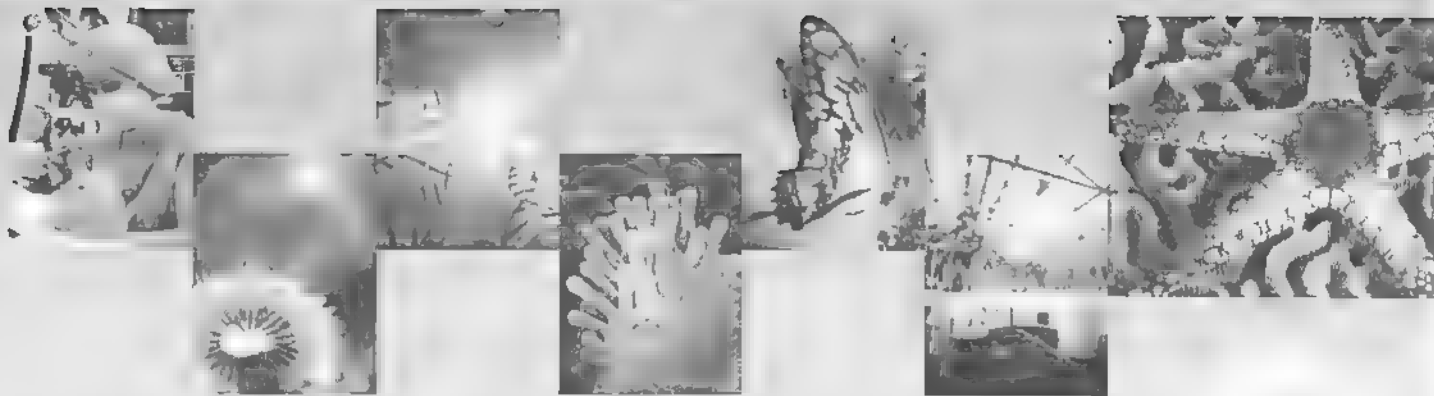
- United valvate sepals, free twisted petals, free stamens, unilocular ovary with marginal placentation
- United valvate sepals, free imbricate petals, free stamens, unilocular ovary with axile placentation
- United valvate sepals, free imbricate petals, epipetalous stamens, unilocular ovary with marginal placentation
- United valvate sepals, free imbricate petals, free stamens, unilocular ovary with marginal placentation

22. Which of the following is not a flower [KCET 1997; BVP 2002]  
(a) Rose (b) Lotus  
(c) Sunflower (d) Passion flower
23. Adaptive heterophylly is found in [MP PMT 2013]  
(a) *Limnophila heterophylla* (b) *Alysicarpus heterophyllus*  
(c) Eucalyptus (d) Jack fruit tree
24. Inferior ovary occurs in [CPMT 1995]  
(a) Cruciferae (b) Compositae  
(c) Malvaceae (d) Ranunculaceae
25. Which of the following are floral characters of Malvaceae [Kerala PMT 2007]  
(a) Pedicellate, bracteate, hermaphrodite, tetramerous, actinomorphic, complete and superior ovary  
(b) Compound spike, flowers bracteate, bracteolate, incomplete, bi or unisexual and hypogynous  
(c) Pedicellate, hermaphrodite, zygomorphic, complete and superior ovary  
(d) Head inflorescence, bracteate, hermaphrodite or unisexual, actinomorphic, or zygomorphic and inferior ovary  
(e) Jointed pedicel, bracteate, bracteolate, hermaphrodite, pentamerous, actinomorphic, complete and superior ovary
26. Coleoptile represents [NCERT; MP PMT 2013]  
(a) Covering of radical (b) Covering of cotyledon  
(c) Covering of plumule (d) Synonym of plumule

## S Answers and Solutions

1	d	2	a	3	a	4	b	5	b
6	d	7	a	8	c	9	c	10	c
11	d	12	b	13	c	14	d	15	c
16	b	17	d	18	b	19	b	20	c
21	d	22	c	23	a	24	b	25	a
26	c								

1. (d) A plant which lives for a few days is called ephemeral because of a very short growing season. Such plant are found near deserts or in very cold countries. e.g., *Arabidopsis* species have life span of 20-28 days.
2. (a) Lodicules are two scale like structures that lie at the base of the ovary of a grass flower including jawar.
3. (a) In heterostyly condition, stamens, style and stigma are of different heights, e.g., *Primula*, *Oxalis*, *Linum* etc.
4. (b) Maize is a monocotyledonous plant where as China rose, Mango and Sunflower are dicotyledonous plants.
5. (b) In Cruciferae  
Bicarpellary : Gynoecium consisting of two carpels fused laterally forming a compound pistil.  
Parietal placentation : Ovary is bi to multicarpellary but unilocular.  
Tetradynamous : There are six free stamens, inner four larger and outer two are small.  
Siliqua fruit : Siliqua is a dry dehiscent fruit develop from bicarpellary, syncarpous and superior ovary.
6. (d) *Raphanobrassica*, *Triticale* and Bromato are some intergeneric hybrids. *Raphanobrassica* (Cabbage) is the result of distant cross between *Raphanus* (Radish) and *Brassica* (Cabbage)
15. (c) Actinomorphic, bisexual, epicalyx 3 to 7, calyx 5 gamosepalous, corolla 5 polypetalous usually adnate at the base to the staminal tube, Androecium indefinite stamens, gynoecium pentacarpellary to indefinite, syncarpous, ovary superior.
17. (d) In members of Cruciferae (Brassicaceae), secretory cells are found which contains myrosin enzyme. This also accompanies the sulphur containing glucosides which hydrolyses them into glucose and isothiocynates (oil).
18. (b) The apex form a tendril called tendrillar, e.g., *Gloriosa*.
20. (c) *Amorphophallus* (simple spadix inflorescence) is largest inflorescence which 5.5 m long.
22. (c) Sunflower (*Helianthus annuus*) is a inflorescence (capitulum). It is a plant of family compositae (Asteraceae).
23. (a) Basal type of placentation, ovary is bicarpellary, syncarpous and unilocular and a single ovule is borne at the base of ovary, e.g., compositae (Marigold, sunflower) In family compositae carpels 2, connate, ovary inferior and basal placentation.



## Chapter 2.2

# Anatomy of Flowering Plants

A group of cells performing a particular function is collectively called as tissue. A tissue may be defined as, "a group of similar or dissimilar cells having common origin and performing specific function".

Tissues are mainly divided into three categories : Meristematic tissues or Meristems, Permanent tissues and Secretory tissues

### Meristematic tissues or Meristems

The word "Meristem" originated from "*Meristos*" (Greek = continuous division) and the term meristem was introduced by Nagell (1858). A group of cells which are much active and capable of showing continuous divisions and redivisions, is called as meristematic tissue. The various characteristic features of the meristems are discussed below :

- (1) They contain immature and young cells and are capable of repeated divisions.
- (2) Intercellular spaces are not present in meristematic tissue.
- (3) They contain a homogeneous thin cellulosic wall.
- (4) They contain large nuclei associated with abundant cytoplasm.
- (5) They are metabolically very active but they do not store food material and further no plastids in them
- (6) Vacuoles are small or absent.
- (7) Meristematic cells are isodiametric in shape.
- (8) Undifferentiated tissue in which cells divide continuously

$G_1 \rightarrow S \rightarrow G_2 \rightarrow M$

### Types of meristems

The meristems may be classified on the basis of their mode of origin, position or function :

**According to origin and development :** On the basis of origin, meristematic tissues are of three types :

(1) **Promeristem or Primordial meristem :** The promeristem originates from embryo and therefore, called primordial or embryonic meristem. It is present in the regions where an organ or a part of plant body is initiated. A group of initial cells that lay down the foundation of an organ or a plant part, is called promeristem. It occupies a small area at the tips of stem and root. The promeristem gives rise to all other meristems including the primary meristem.

(2) **Primary meristem :** A primary meristem originates from promeristem and retains its meristematic activity. It is located in the apices of roots, stems and the leaf primordia. Primary meristem gives rise to the primary permanent tissue

(3) **Secondary Meristem :** They always arise in permanent tissues and have no typical promeristem. Some living permanent cells may regain the meristematic nature. This process in which permanent tissue regains meristematic nature is called dedifferentiation. The secondary meristems are so called because they originate from permanent cells. The phellogen or cork cambium arising from epidermis, cortex or other cells during secondary growth, is an important example of secondary meristem. The secondary meristems produce secondary tissues in the plant body and add new cells for effective protection and repair

**According to position :** On the basis of their position in the plant body meristems are classified into three categories :

(1) **Apical meristem :** This meristem is located at the growing apices of main and lateral shoots and roots. These cells are responsible for linear growth of an organ. Solitary apical cells occur in ferns and other Pteridophytes while apical initials are found in other vascular plants.

(2) **Intercalary meristem** : These are the portions of apical meristems which are separated from the apex during the growth of axis and formation of permanent tissues. It is present mostly at the base of node (e.g., *Mentha viridis*, Mint), base of internode (e.g., stem of many monocots viz., Wheat, Paddy, Grasses, Pteridophytes like *Equisetum*) or at the base of the leaf (e.g., *Pinus*). The intercalary meristems ultimately disappear and give rise to permanent tissues.

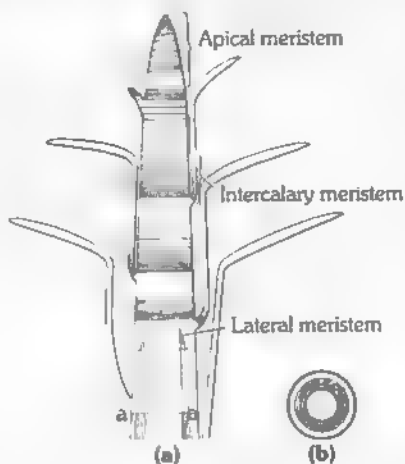


Fig : 2.2-1 Various meristematic tissue

(3) **Lateral meristem** : These meristems occur laterally in the axis, parallel to the sides of stems and roots. This meristem consists of initials which divide mainly in one plane (periclinal) and results in increase in the diameter of an organ. The cambium of vascular bundles (Fascicular, interfascicular and extrastelar cambium) and the cork cambium or phellogen belongs to this category and are found in dicotyledons and gymnosperms.

**According to function** : Haberlandt in 1890 classified the primary meristem at the apex of stem under the following three types :

(1) **Protoderm** : It is the outermost layer of the apical meristem which develops into the epidermis or epidermal tissue system.

(2) **Procambium** : It occurs inside the protoderm. Some of the cells of young growing region which by their elongation and differentiation give rise to primary vascular tissue, constitute the procambium.

(3) **Ground meristem** : It constitutes the major part of the apical meristem which develops ground tissues like hypodermis, cortex, endodermis, pericycle, pith and medullary rays.

**According to plane of cell division** : On the basis of their plane of cell division meristem are classified into three categories :

(1) **Mass meristem** : The cells divide anticleinally in all planes, so mass of cells is formed. e.g., formation of spores, cortex, pith, endosperm.

(2) **Plate meristem** : The cells divide anticleinally in two planes, so plate like area increased. e.g., formation of epidermis and lamina of leaves.

(3) **Rib or File meristem** : The cells divide anticleinally in one plane, so row or column of cells is formed. e.g., formation of lateral root

### Structure and organisation of apical meristem

(1) **Vegetative shoot apex** : Shoot apex was first recognized by Wolff (1759) shoot apex is derived from meristem present in plumule of embryo and occurs at the tip of stem and its branches as terminal bud. It also occurs in the inactive state in the axils of leaves as lateral buds. The tip of the shoot apex is dome-shaped and from its flanks at the base of the dome divide to form one or more leaf primordia. This continues throughout the vegetative phase. Many theories have been put forward to explain shoot apex, such as :

(i) **Apical cell theory** : This theory was proposed by Nageli (1858). According to this theory, shoot apical meristem consists of single apical cell. This theory is applicable in case of higher algae, bryophytes and in many pteridophytes but not in higher plants (i.e., gymnosperms and angiosperms).

(ii) **Histogen theory** : It was proposed by Hanstein (1870) According to this theory, the shoot apical meristem consists of three distinct meristematic zones or layers (or histogens)

(a) **Dermatogen** : Outermost layer and it forms epidermis and epidermal tissue system.

(b) **Periblem** : It is the middle layer which gives rise to cortex and endodermis.

(c) **Plerome** : The innermost layer forms pith and stele.

(iii) **Tunica corpus theory** : This theory was proposed by Schmidt (1924). According to this theory, the shoot apex consists of two distinct zones.

(a) **Tunica** : It is mostly single layered and forms epidermis. The cells of tunica are smaller than corpus. The tunica shows only anticlinal division and it is responsible for surface growth.

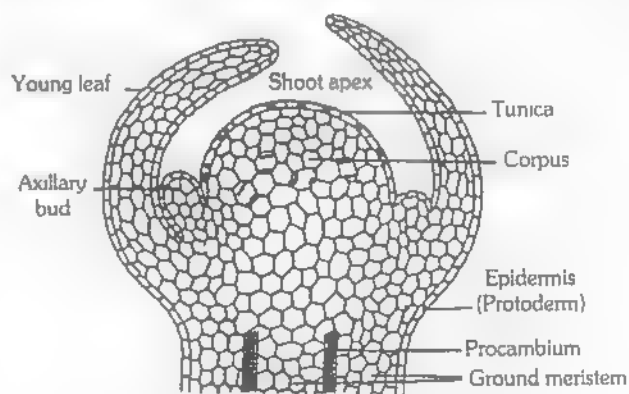


Fig : 2.2-2 L.S. Vegetative shoot apex

(b) **Corpus** : It represents the central core with larger cells. Corpus shows divisions in all planes and it is responsible for volume growth.

Popham and Chan (1950) introduced the term mantle for tunica and core for corpus

(2) **Root apex** : A group of initial cells, present at the subterminal region of the growing root tip, which is protected by a root cap, is called root apical meristem or root apex. It is embryonic in origin and formed from the radicle part of embryo. However, in adventitious roots it is produced from derivatives of root apex. According to Hanstein (1870) root apex of most of the dicotyledons also consists of three meristematic zones - **plerome**, **periblem** and **dermatogen** (fourth meristem calyptragen to form root cap only in monocots).

(i) **Dermatogen** : It gives rise to epiblemma or piliferous layer or rhizodermis.

(ii) **Periblem** : It gives rise to cortex including endodermis..

(iii) **Plerome** : It gives rise to vascular tissue including pith.

Regarding the apical organisation of root following theories have been put forward.

**Korper-Kappe theory** : It was proposed by Schuepp (1917). This theory is comparable with the tunica and corpus theory of shoot apex. Korper means body and Kappe means cap.

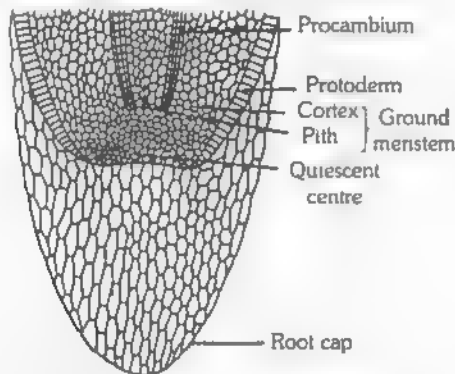


Fig : 2.2-3 L.S. Root apical meristem

**Quiescent centre theory** : It was proposed by Clowes (1961) in maize. According to him, in addition to actively dividing cells, a zone of inactive cells is present in the central part of the root apex called quiescent centre.

The cells in this region have light cytoplasm, small nuclei, lower concentration of DNA, RNA and protein.

(3) **Reproductive apex** : During reproductive phase, the vegetative apices are converted into reproductive apices. Before conversion, the apex stops producing leaf primordia. The summit of the apex which remained inactive during the vegetative phase, starts dividing. As a result of cell divisions, the apical meristem undergoes change in shape and increase in size. The apex may develop into a flower or an inflorescence.

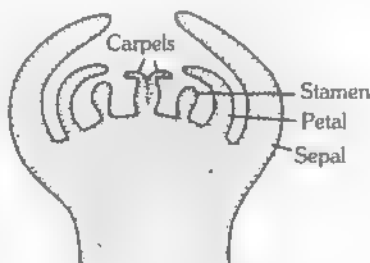


Fig : 2.2-4 L.S. Reproductive apex (diagrammatic)

## Permanent tissues

Permanent tissues are made up of mature cells which have lost the capacity to divide and have attained a permanent shape, size and function due to division and differentiation in meristematic tissues. The cells of these tissues are either living or dead, thin-walled or thick-walled. Permanent tissues are of following types :

### Simple permanent tissues

Simple tissues are a group of cells which are all alike in origin, form and function. They are further grouped under three categories :

(1) **Parenchyma** : Parenchyma is most simple and unspecialized tissue which is concerned mainly with the vegetative activities of the plant.

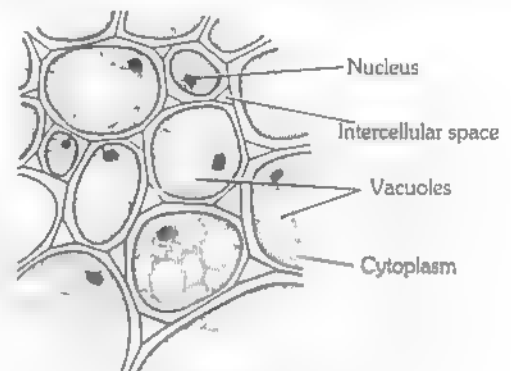


Fig : 2.2-5 Parenchyma in T.S.

The main characteristics of parenchyma cells are :

(i) The cells are isodiametric, living, thin walled, soft, possess a distinct nucleus, having well developed intercellular spaces, vacuolated cytoplasm and cellulosic cell wall.

(ii) The shape may be oval, spherical, cylindrical, rectangular and stellate (star shaped) in leaf petioles of banana and canna and some hydrophytes.

(iii) This tissue is generally present in roots, stems, leaves, flowers, fruits and seeds.

(iv) If they enclose large air spaces they are called as aerenchyma; if they develop chlorophyll, they are called as chlorenchyma and if they are elongated cells with tapering ends, they are called as prosenchyma.

**Functions** : They perform the following functions .

(i) Storage of food materials. e.g., Carrot, Beetroot etc.

(ii) Chlorenchyma helps in photosynthesis Aerenchyma helps in floating of the aquatic plants (Hydrophytes) and also helps in gaseous exchange during respiration and photosynthesis e.g., Hydrilla.

(iii) In turgid state they give rigidity to the plant organs.

(iv) In emergency they behave like meristematic cells and help in healing of the various plant injuries.

(v) Sometimes they store secretory substances (ergastic substance) such as tannins, resins and gums and they are called as idioblasts.

(2) **Collenchyma** : The term collenchyma was coined by Schleiden (1839). It is the tissue of primary body. The main characteristics of collenchyma are given below :

(i) The cells of this tissue contain protoplasm and are living without intercellular spaces. The cell walls are thickened at the corners and are made up of cellulose, hemicellulose and pectin

(ii) They are compactly arranged cells, oval, spherical or polygonal in outline. The tissue is elastic, extensible and have capacity to expand.

(iii) Collenchyma occurs chiefly in the hypodermis of dicotyledonous stems (herbaceous, climbers or plants e.g. *Cucurbita*, *Helianthus*) and leaves. They are usually absent in monocots and in roots

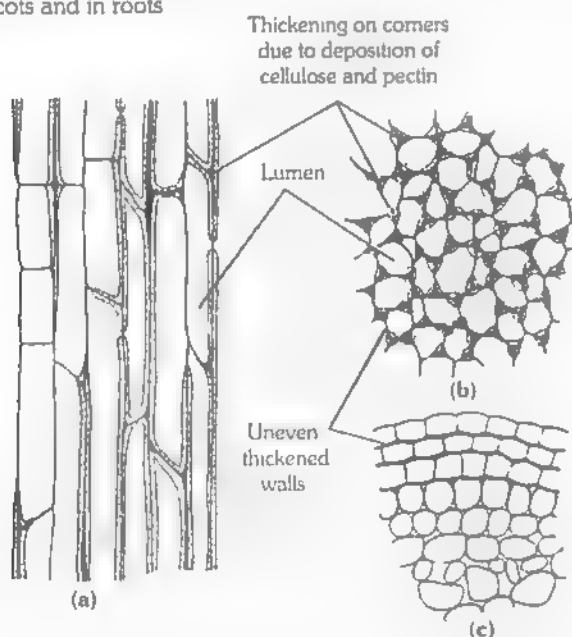


Fig : 2.2-6 (a) Collenchyma L.S. (b) and (c) T.S. of the same

**Types of collenchyma** : Majumdar (1941) divided collenchyma into three types on the basis of thickening :

(i) **Angular collenchyma** : When the thickening of the cells is confined to the corners of the cells. e.g., *Tagetes*, *Tomato*, *Datura*, *Potato*, etc.

(ii) **Plate or Lamellar collenchyma** : When the thickenings are present in the tangential walls. e.g. hypodermis of sunflower stem

(iii) **Lacunar or Tubular collenchyma** : If the thickened cell wall is associated with intercellular spaces of the adjacent cells. e.g. leaf petioles of compositae (asteraceae) and malvaceae etc hypodermis of *Cucurbita* stem, *Salvia*, *Malva*

#### Functions

(i) Provide mechanical support to petiole, pedicels, branches of stem, roots and fruits

(ii) If they contain chlorophyll they help in photosynthesis

(iii) It is present at the margins of some leaves and resists tearing and bending effect of the wind

(3) **Sclerenchyma** : It was discovered and coined by Mettenius (1805)

The main features of sclerenchyma are :

(i) It consists of thick-walled dead cells.

(ii) The cells vary in shape, size and origin.

(iii) In the beginning the cells are living and have protoplasm but due to deposition of impermeable secondary walls (lignin) they become dead, thick and hard

**Types of sclerenchyma** : They are of two types :

(i) **Sclerenchymatous fibres** : These are greatly elongated and tapering at both the ends. The fully developed fibre cells are always dead. They are polygonal in transverse section and walls are highly lignified. Intercellular spaces are absent and lumen is highly obliterated. The walls show simple and oblique pits. They provide mechanical strength to the plant. Some of the longest fibre yielding plants are *Linum usitatissimum* (Flax or Alsi), *Corchorus*, *Cannabis*, etc. The fibres are present in hypodermis of monocot stem, in pericycle of many dicots, in secondary wood and vascular bundle sheath in monocot stems. There are three different kinds of fibres :



Fig : 2.2-7 Sclerenchymatous fibres (a) L.S. (b) T.S.

(a) **Bast fibres** : The fibres present in the pericycle (e.g., *Cannabis sativa* / Hemp or Bhang), *Linum usitatissimum* and phloem (e.g., *Corchorus capsularis* (Jute), *Hibiscus cannabinus* (Patan), *Calotropis*, *Nerium*, *Sunn hemp* etc.). These fibre are also known as extraxylary fibres

(b) **Wood fibres** : Those fibres which are associated with wood or xylem have bordered pits are known as wood fibres. Thick walled wood fibres having simple pits are called libriform fibres whereas thin walled wood fibres having bordered pits are called fibre-tracheids. A specific type of wood fibre is produced by *Quercus robur* and is called gelatinous or mucilaginous fibres.

(c) **Surface fibres** : The fibres present over surface of plant organs are called surface fibres. e.g., Cotton fibres found in the testa of seeds, mesocarp fibres of Coconut (*Cocos nucifera*).

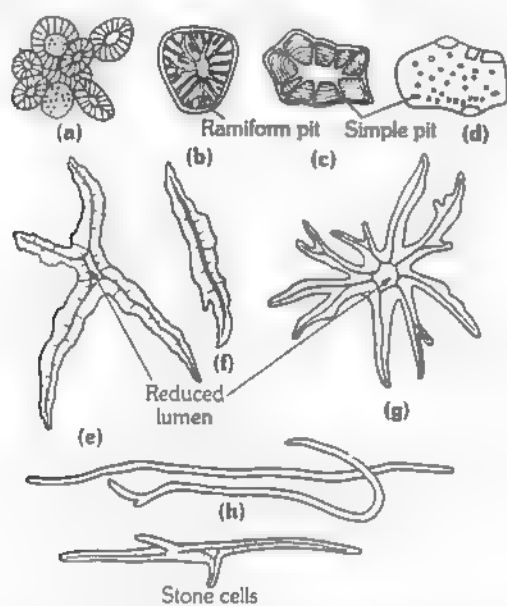
(ii) **Stone cells or Sclereids** : They are lignified, extremely thick walled so that the lumen of the cells is almost obliterated and may be spherical, oval, cylindrical, T-shaped and even stellate. They are generally found in hard parts of the plant, e.g., endocarp of Walnut and Coconut. The sclereids provide mechanical support and hardness to the soft parts



**Kind of sclereids :** They are of five types :

(a) **Brachysclereids or stone cells :** These are small and more or less isodiametric in shape. They occur in the cortex, pith, phloem, and pulp of fruits (e.g., *Pyrus*).

(b) **Macrosclereids or rod cells :** These are rod-shaped elongated sclereids usually found in the leaves, cortex of stem and outer seed coats.



**Fig : 2.2-8** Stone cells (a, b) from pulp of pear, (c, d) from stem cortex of Hoya, (e, f) from petiole of *Camellia*, (g) from stem cortex of *Trochodendron*, (h) from mesophyll cells of fig leaf

(c) **Osteosclereids or bone cells :** These are bone or barrel-shaped sclereids dilated at their ends. e.g., leaf of *Hakea*.

(d) **Astrosclereids or stellate cells :** These are star-shaped sclereids with extreme lobes or arms. e.g., leaf of *Nymphaea*.

(e) **Trichosclereids or internal hairs :** These are hair-like sclereids found in the intercellular spaces in the leaves and stem of some hydrophytes.

#### Complex permanent tissues

A group of more than one type of cells having common origin and working together as a unit, is called complex permanent tissue. The important complex tissues in vascular plants are : xylem and phloem. Both these tissues are together called vascular tissue.

(1) **Xylem :** The term xylem was introduced by Nageli (1858). Xylem is a conducting tissue which conducts water and mineral nutrients upwards from the root to the leaves. It is also known as hadrome (Haberlandt).

**On the basis of origin xylem is of two types :**

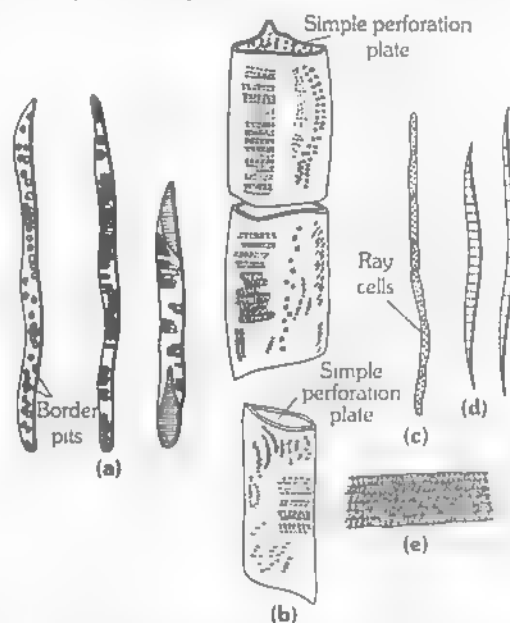
(i) **Primary xylem :** It is derived from procambium during primary growth. It consists of protoxylem and metaxylem.

(ii) **Secondary xylem :** It is formed from vascular cambium during secondary growth

**Xylem is composed of four types of cells :**

(i) **Tracheids :** Term "Tracheids" was given by Sanio (1863). The tracheids are elongated tube-like cells with tapering or rounded or oval ends with hard and lignified walls.

The cells are without protoplast and are dead on maturity. Tracheids possess bordered pits. Maximum bordered pits are formed in gymnospermous tracheids. They also possess various kinds of thickenings, e.g., annular, spiral, scalariform, reticulate or pitted tracheids. All the vascular plants have tracheids in their xylem. The main function of tracheids is to conduct water and minerals from the root to the leaf. They also provide strength and mechanical support to the plant.



**Fig : 2.2-9** Xylem-(a) Tracheids, (b) Tracheae, (c) and (e) Xylem parenchyma (d) Wood fibres (wood sclerenchyma)

(ii) **Xylem vessels or Tracheae :** Vessels are rows of elongated tube-like cells, placed end to end with their end walls dissolved. Vessels are multicellular with wide lumen. The vessels may be annular, spiral, scalariform, reticulate or pitted. Vessels are absent in pteridophytes and gymnosperms (except *Ephedra*, *Gnetum*, *Selaginella*, *Pteridium*). In angiosperms (porous wood) vessels are always present (Vessels are absent in family - Winteraceae, Trochodendraceae and Tepacenpaceae of Angiosperm i.e. *Lotus*, *Wintera*, *Trochodendron*). It also provides mechanical support to the plant and helps in conduction. On the basis of distribution and size of vessels, porous wood is of two types :

(a) **Diffuse porous wood (Primitive) :** Vessels of same size are uniformly distributed throughout the growth or annual ring e.g., *Pyrus*, *Azadirachta*, *Eucalyptus*, *Mangifera sp.*, *Betula*. They are characteristics of plants growing in tropical region.

(b) **Ring porous wood (Advanced) :** Large vessels are formed in early wood when the need of water is great and small vessels are formed in late wood e.g. *Quercus*, *Morus*, *Cassia*, *Delbergia*, *Tilea sp*

(iii) **Wood (xylem) parenchyma** : These are the living parenchymatous cells. As found associated with xylem they are known as wood parenchyma. They serve for the storage of reserve food and also help in conduction of water upwards through tracheids and vessels.

(iv) **Wood (xylem) fibres** : The long, slender, pointed, dead and sclerenchymatous cells found associated with xylem are termed wood fibres. They aid the mechanical strength of xylem and various organs of plant body

(2) **Phloem (bast)** : Term "Phloem" was given by Nageli. Its main function is the transport of organic food materials from leaves to stem and roots in a downward direction. It is also known as leptome.

**On the basis of position phloem is of three types :**

(i) **External phloem** : It is normal type and present outside the xylem e.g., Mostly angiosperms and gymnosperms.

(ii) **Internal or Intraxylary phloem** : It originates from procambium and is primary phloem which occurs on innerside of primary xylem. It is primary anomalous structure. e.g., Members of Apocynaceae, Asclepiadaceae, Convolvulaceae, Solanaceae.

(iii) **Induced or Interxylary phloem** : It originates from cambium and is secondary phloem which occurs in groups within the secondary xylem. It is secondary anomalous structure. e.g., *Leptadenia*, *Salvadora*, *Chenopodium*, *Boerhaavia*, *Amaranthus*.

**On the basis of origin, phloem is of two types :**

(i) **Primary phloem** : It is formed by procambium during primary growth. It may or may not show differentiation in protophloem (consists of sieve elements and parenchyma) and metaphloem (develop after protophloem and consists of sieve elements, parenchyma and fibre).

During the primary growth the protophloem elements are crushed by the surrounding tissues and disappear. This process is known as obliteration

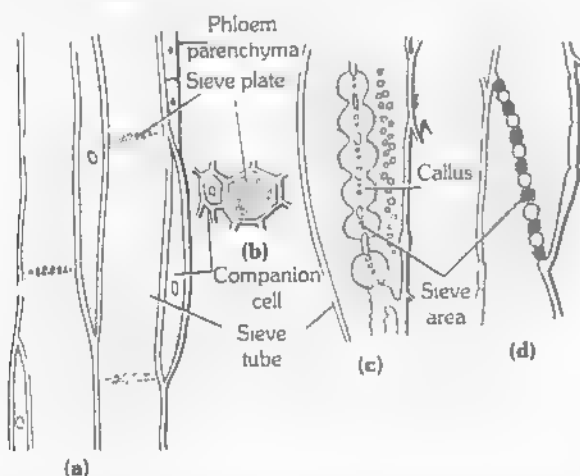


Fig : 2.2-10 Parts of Phloem (a) L.S. of phloem tissue, (b) T.S. of phloem tissue, (c) Sieve tubes of *Vitis*, (d) L.S. of sieve plate

(ii) **Secondary phloem** : It is produced during secondary growth by vascular cambium.

It consists of the following elements :

#### Sieve element

(i) They are long tube-like cells placed end to end, forming a continuous channel in the plant parts.

(ii) Their cell wall is made up of cellulose and transverse wall is perforated like a normal sieve and hence they are called as sieve tubes

(iii) Nucleus is not found in the mature cells.

(iv) Sieve pores in winter get plugged with a substance called callose (soluble) and hence the transport of food is retarded. But in spring and summer, this callose gets dissolved and hence transport of food is rapid again.

(v) Their main function is to translocate the food material from one part to the other.

(vi) P-protein is found in sieve tubes.

#### Companion cells

(i) They are thin-walled, more or less elongated cells and which are associated with sieve tubes.

(ii) They are connected with the sieve tube through sieve pore.

(iii) They contain nucleus and are therefore, living in nature.

(iv) They are not found in pteridophytes and gymnosperms but are always present in angiosperms

**Phloem parenchyma** : The parenchyma associated with the phloem is called phloem parenchyma. The cells are elongated with rounded ends and possess cellulosic cell walls. These cells are living and store food reserves in the form of starch and fats. They are present in pteridophytes and most of dicotyledonous angiosperms. They are absent in monocots and few dicots like *Ranunculus*.

**Phloem or Bast fibres** : The sclerenchymatous fibres associated with the phloem are called as phloem fibres or bast fibres. The fibres are elongated lignified sclerenchymatous cells with tapering ends and with simple pits. They are non-living cells that provide mechanical support to the organs. Commercial jute fibres are obtained from phloem fibres.

#### Special or Secretory tissues

These tissue perform special function in plants, e.g., secretion of resins gum, oil and latex

These tissues are of two types .

(1) **Laticiferous tissues** : They are made up of thin walled, elongated, branched and multinucleate (coenocytic) structures that contain colourless, milky or yellow coloured juice called latex. These occur irregularly distributed in the mass of parenchymatous cells. Latex is contained inside the laticiferous tissue which is of two types :

(i) **Latex cells** : A laticiferous cell is a highly branched cell with long slender processes ramifying in all directions in the ground tissue of the organ. They do not fuse and do not form network. Plants having such tissues are called simple or non-articulated laticifers. e.g., *Calotropis* (Asclepiadaceae), *Nerium*, *Vinca* (Apocynaceae), *Euphorbia* (Euphorbiaceae), *Ficus* (Moraceae).

(ii) **Latex vessels** : They are formed due to fusion of cells and form network like structure in all directions. At maturity, they form a highly ramifying system of channels full of latex inside the organ. Plants having such tissues are called compound or articulated laticifers. e.g., *Argemone*, *Papaver* (Papaveraceae), *Sonchus* (Compositae), *Hevea*, *Manihot* (Euphorbiaceae).

(2) **Glandular tissue** : This is a highly specialized tissue consisting of glands, discharging diverse functions, including secretory and excretory. Glands may be external or internal.

(i) **External glands** : They generally occur on the epidermis of stem and leaves as glandular hair in *Plumbago* and *Boerhaavia*, stinging hair secrete poisonous substance in *Urtica dioica*, nectar secreting glands in flowers or leaves. e.g., *Rutaceae* and *Euphorbiaceae*. Digestive enzyme secreting glands in insectivorous plants e.g., *Drosera* (Sundew), *Nepenthes* (Pitcher plant).

(ii) **Internal glands** : These are present internally and are of several types e.g., oil glands in *Citrus* and *Eucalyptus*, resinous ducts in *Pinus*, these resin canals are schizogenous in nature. mucilage canals in *Cycas*. Water secreting glands (hydathodes) in *Colocasia* (present at the tip of leaves), *Tropaeolum* (along margin), etc. The glands which secrete essential oil are called osmophores (osmotrophs).

## The tissue system

Several tissues may collectively perform the same function. A collection of tissues performing the same general function is known as a "Tissue System". According to Sachs (1975) there are three major tissue systems in plants as follows :

(1) **Epidermal tissue system** : The tissues of this system originate from the outermost layer of apical meristem. It forms the outermost covering of various plant organs which remains in direct contact with the environment.

**Epidermis** : Epidermis is composed of single layer of cells. These cells vary in their shape and size and form a continuous layer interrupted by stomata. In some cases epidermis may be multilayered e.g. *Ficus*, *Nerium*, *Peperomia*, *Begonia* etc.

The epidermal cells are living, parenchymatous, and compactly arranged without intercellular spaces.

Certain epidermal cells of some plants or plant parts are differentiated into variety of cell types :

(i) In aerial roots, the multiple epidermal cells are modified to velamen, which absorbs water from the atmosphere (e.g., Orchids).

(ii) Some of the cells in the leaves of grasses are comparatively very large, called bulliform or motor cells. It is hygroscopic in nature. e.g., *Ammophila*. They are thin-walled and contain big central vacuoles filled with water. They play an important role in the folding and unfolding of leaves.

(iii) Some members of Gramineae and Cyperaceae possess two types of epidermal cells : the long cells and the short cells. The short cells may be cork cells or silica cells.

**Cuticle and Wax** : In aerial parts, epidermis is covered by cuticle. The epidermal cells secrete a waxy substance called cutin, which forms a layer of variable thickness (the cuticle) within and on the outer surface of its all walls. It helps in reducing the loss of water by evaporation. Usually the cuticle is covered with wax which may be deposited in the form of granules, rods, crusts or viscous semiliquid masses. Other substances deposited on the cuticle surface may be oil, resin, silicon and salts (cystoliths are crystals of calcium carbonate, e.g., *Ficus*. Druse and Raphides, e.g., *Pistia* are crystals of calcium oxalate). Thick cuticle are found in leaves of dry habitats plants.

**Stomata** : Stomata are minute apertures in the epidermis. Each aperture is bounded by two kidney shaped cells, called guard cells. Stomata are absent in roots. In xerophytes the stomata are sunken in grooves due to which rate of transpiration is greatly reduced (e.g. *Nerium*). Usually there is a large air cavity below each aperture, it is called substomatal cavity. In some species the guard cells are surrounded by subsidiary cells or accessory cells which differ morphologically as well as ontogenitally from the other epidermal cells. In monocots subsidiary cells and guard cells originated from same cell e.g., *Doob*, Maize guard cells are dumb bell shape. Stomata are scattered in dicot leaves but they are arranged in rows in monocots.

**Trichomes** : These are epidermal outgrowths present temporarily or permanently on almost all plant parts. They may be unicellular or multicellular and vary in size and shape in different species. They may be of different types : stellate hair, glandular hair, short glandular hair, floccose hair, urticating hair and stinging hair. The trichomes serve for checking excess loss of water and for protection.

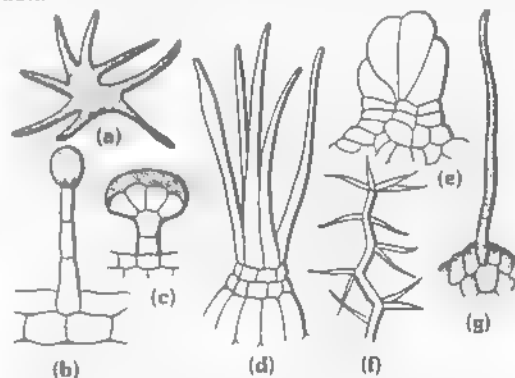


Fig : 2.2-11 Appendages of epidermis of leaves  
(a) Stellate hair of *Alyssum*, (b) Glandular hair of *Pelargonium* (c) Short glandular hair of *Lavandula*, (d) Floccose hair of *Malva*, (e) Glandular hair of *Solanum*, (f) Urticating hair of *Verbascum*, (g) Stinging hair of *Cestus*

**Root hairs** : They are enlargements of special epiblasts called trichoblasts and occur in a particular zone of young root called root hair zone. A root hair cell has vacuolated protoplast with nucleus present towards the apical part of hair. They are specialised to absorb water from soil crevices. They also hold soil particles.

(2) **Ground or Fundamental tissue system** : Ground tissue system includes all the tissues of plant body except epidermal tissue system and vascular tissues. It forms the bulk of body. This tissue system mainly originates from ground meristem. The ground tissues constitute the following parts :

**Cortex** : It lies between epidermis and the pericycle. The cortex is distinct in dicotyledons but not in monocotyledons where there is no clear demarcation between cortex and pith. It is further differentiated into :

**Hypodermis** : It is collenchymatous in dicot stem and sclerenchymatous in monocot stem. It provides strength.

**General cortex** : It consists of parenchymatous cells. Its main function is storage of food.

**Endodermis (Starch sheath)** : It is mostly single layered and is made up of parenchymatous barrel shaped compactly arranged cells. The inner and radial or transverse wall of endodermal cells have casparian strips of suberin. In roots thick walled endodermal cells are interrupted by thin walled cells just outside the protoxylem patches. These thin walled endodermal cells are called passage cells or transfusion cells. A fully developed endodermis is found in all types of roots. Endodermis with characteristic casparian bands is absent in woody dicot stem, monocot stem and leaves of angiosperms.

Endodermis behaves as water tight dam to check the loss of water and air dam to check the entry of air in xylem elements. Endodermis is internal protective tissue.

**Pericycle** : It is a single layered or multilayered cylinder of thin-walled or thick-walled cells present between the endodermis and vascular tissues. In some cases, the pericycle is made up of many layers of sclerenchymatous cells (*Cucurbita* stem) or in the form of alternating bands of thin-walled and thick-walled cells (*Sunflower* stem). In case of roots, the pericycle is made up of thin-walled parenchymatous cells which later on gives rise to lateral roots. In dicot roots the cork cambium originates in the pericycle which results in the formation of periderm. Pericycle also gives rise to a part of vascular cambium in dicot roots.

**Pith or Medulla** : It occupies the central part in dicot stem, and monocot root. It is mostly made up of parenchymatous cells. In dicot root pith is completely obliterated by the metaxylem elements. In dicot stem the pith cells between the vascular bundles become radially elongated and known as primary medullary rays or pith rays. They help in lateral translocation.

(3) **Vascular tissue system** : The central cylinder of the shoot or root surrounded by cortex is called stele. The varying number of vascular bundles formed inside the stele constitute vascular tissue system. Xylem, phloem and cambium are the major parts of the vascular bundle. Vascular bundle may be of following types :

**Radial** : The xylem and phloem strands alternate with each other separated by parenchymatous cells. Such kinds of vascular bundles are called radial and found mainly in roots.

**Conjoint** : A vascular bundle having both xylem and phloem together, is called conjoint. Normally the xylem and phloem occur in the same radius. They occur in stems.

**Collateral** : A vascular bundle in which the phloem lies towards outer side and xylem towards inner side, is called collateral, e.g., *Sunflower*.

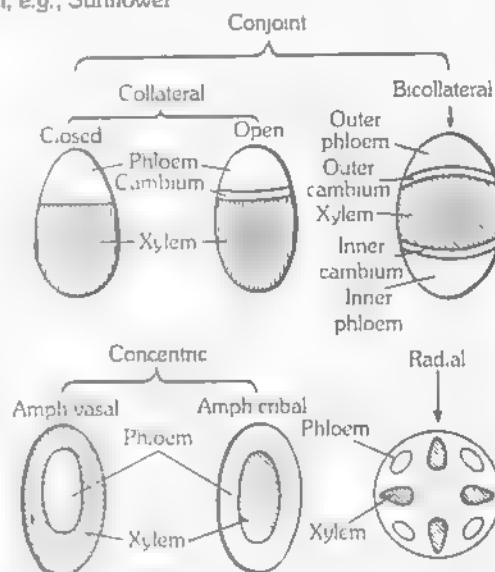


Fig : 2.2-12 Different types of vascular bundles

Collateral bundle having a cambium between xylem and phloem is said to be of the open type, e.g., *Dicot* stem.

Collateral bundle lacking a cambium between xylem and phloem is said to be of the closed type, e.g., *Monocot* stem.

**Bicollateral** : A vascular bundle having the phloem strands on both outer and inner side of xylem, is called bicollateral. e.g., *Cucurbita*, *Lagenaria*. Bicollateral vascular bundles are found in family *Cucurbitaceae*, *Solanaceae* and *Myrtaceae*.

**Concentric** : A vascular bundle in which one tissue is completely surrounded by the other, is called concentric. The concentric bundles are of two types :

(i) **Amphivasal (Leptocentric)** : The phloem lies in the centre and remains completely surrounded by xylem. e.g., *Dracaena*, *Yucca*.

(ii) **Amphicribal (Hadrocentric)** : The xylem lies in the centre and remains completely surrounded by phloem. e.g., *Ferns*.

#### Stelar system

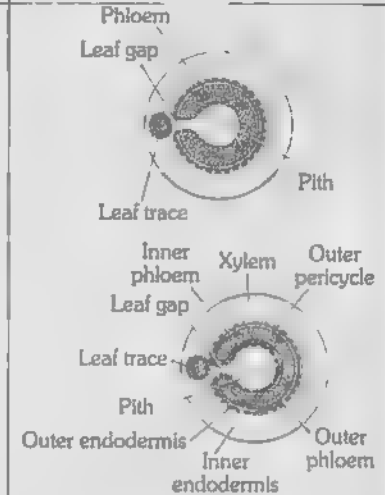
Stelar theory was proposed by Van Tieghem and Douliot (1886). According to this concept primary body of root and stem are basically alike anatomically i.e. each consists of a central stele surrounded by cortex. Stele includes the vascular tissues and the ground tissue like pericycle and pith, when present.

Table : 2.2-1 The types of steles are

Types of stele	Diagrammatic representation
(1) <b>Protostele</b> : This term was given by Jeffrey. It is the simplest and most primitive type of stele in which central core of xylem surround by phloem.	
(i) <b>Haplostele</b> : It consists of a smooth core of xylem which is surrounded by a ring of phloem. e.g., <i>Rhynia</i> , <i>Selaginella</i> , <i>Lycopodium</i> , etc.	
(ii) <b>Actinostele</b> : Protostele having star shaped xylem core with many radiating arms called actinostele. e.g. <i>Psilotum</i> , <i>Lycopodium</i> etc.	
(iii) <b>Plectostele</b> : A protostele in which xylem core broken into a number of parallel plates is known as plectostele. e.g., <i>Lycopodium clavatum</i> .	
(iv) <b>Mixed protostele</b> : A protostele in which xylem is broken into small group or patches is known as mixed protostele. e.g., <i>Lycopodium cernuum</i> , <i>Hymenophyllum demissum</i> , etc.	
(2) <b>Siphonostele</b> : A protostele with central pith is called siphonostele or medullated stele. It is considered to be derived phylogenetically from protostele and thus represents an advance form. It is of two types :	
(i) <b>Ectophloic siphonostele</b> : When phloem occurs on the outer side of xylem. e.g., <i>Osmunda</i> , <i>Equisetum</i>	
(ii) <b>Amphiphloic siphonostele</b> : When phloem is present on both external and internal sides of the xylem e.g., <i>Marsilea</i> , <i>Adiantum</i> .	

### Modification of siphonostele

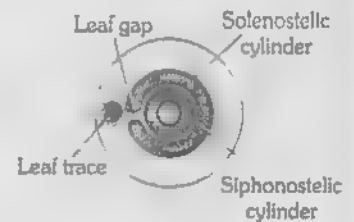
(i) **Solenostele** : A siphonostele with non-overlapping leaf gaps is known as solenostele. It may be ectophloic or amphiphloic.



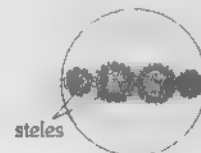
(ii) **Dictyostele** : A siphonostele with overlapping leaf gaps is known as dictyostele. It has many scattered vascular strands called as **meristeles**. e.g., *Dryopteris*, *Pteris*, *Ophioglossum*.



(iii) **Polycyclic stele** : When vascular tissue is present in the form of two or more concentric cylinders. e.g., *Pteridium aquilinum*, *Marattia*. It may be polycyclic solenostele or polycyclic dictyostele.



(iv) **Polysteles** : Sometimes more than one steles are present in the axis of some pteridophytes e.g. 2 steles in *Selaginella kraussiana*, 16 steles in *S. laevigata*.



### Internal structure of root, stem and leaf

Table : 2.2-2 Functions of different organs and tissues of a plant tissue system

	Roots	Stems	Leaves
(i) <b>Functions</b>	(i) Absorb water and minerals (ii) Anchor plant. (iii) Store materials	(i) Transport water and nutrients (ii) Support leaves. (iii) Help to store materials	Carry on photosynthesis.

(ii) Tissues			
(a) Epidermis	Root hairs absorb water and minerals.	Protect inner tissues.	Stomata carry on gas exchange.
(b) Cortex	Store products of photosynthesis and water.	Carry on photosynthesis if green.	
(c) Endodermis	Regulates passage of minerals into vascular cylinder.	Regulates passage of minerals into vascular tissue, if present.	Regulates passage of minerals into vascular tissue if present.
(d) Vascular bundle	Transport water and nutrients.	Transport water and nutrients.	Transport water and nutrients.
(e) Pith	Store products of photosynthesis and water.	Store products of photosynthesis.	
(f) Mesophyll			Carry on gaseous exchange and photosynthesis.
(i) Spongy layer			
(ii) Palisade layer			

Table : 2.2-3

### Difference between internal structure of root and stem

Description	Root	Stem
(i) Epidermis or Epiblema	Epiblema or piliferous layer without cuticle	Epidermis usually with cuticle
(ii) Epidermal Hairs	Unicellular.	Usually multicellular
(iii) Hypodermis	Absent	Present - Collenchymatous or sclerenchymatous

(iv) Chlorenchyma	Absent.	Usually present in young stems but absent in old stem.
(v) Endodermis	Very distinct.	Poorly developed or absent
(vi) Vascular bundle	Radial	Conjoint collateral or bicollateral or concentric
(vii) Xylem	Exarch.	Endarch.

**Origin of Lateral roots :** Lateral roots arise endogenously, i.e. form the cells inside the endodermis. They arise from pericycle cells.

Table : 2.2-4 Difference between dicot and monocot leaf

Character	Dicot leaf	Monocot leaf
(i) Type of leaf	Dorsiventral (bifacial).	Isobilateral.
(ii) Stomata	Present on lower epidermis.	Equal on lower and upper epidermis (amphistomatic)
(iii) Mesophyll	Made up of two types of tissues (a) Palisade parenchyma, which is columnar with large intercellular spaces (b) Spongy parenchyma, which is spongy with large intercellular spaces	Only spongy parenchyma is present which has very small intercellular spaces
(iv) Bundle sheath	Made up of parenchyma cells. Just above and below the vascular bundle some parenchymatous cells or sclerenchymatous cells are present (upto epidermis).	Made up of parenchyma cells but just above and below the vascular bundles are found sclerenchymatous cells (upto epidermis)
(v) Bulliform or Subsieve cells	Absent.	Present on upper epidermis

Kranz type anatomy occurs in both monocot and dicot leaves of some tropical and arid areas. Kranz anatomy is characteristic feature of C<sub>4</sub> plants. The mesophyll is undifferentiated and occurs in concentric layers around vascular bundles. Cells of bundle sheath possess large chloroplast.

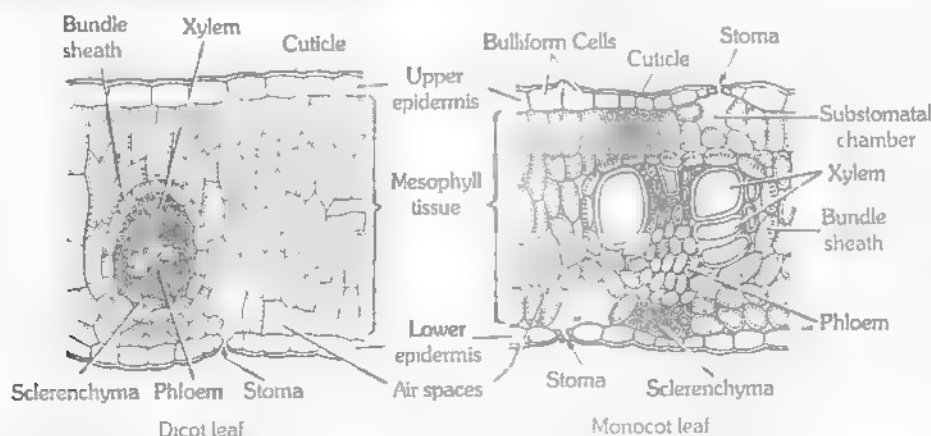


Fig : 2.2-13 Comparison of T.S. of a dicot and monocot leaf

Table : 2.2-5 Difference between dicot and monocot stem

Characters	Monocotyledonous Stem	Dicotyledonous Stem
(i) Epidermis	Present, cells comparatively smaller and without hair	Present, cells larger and with hair
(ii) Hypodermis	Sclerenchymatous (non-green)	Collenchymatous (green)
(iii) Cortex	Absent, but ground tissue is present from hypodermis to the centre of stem	Made up of several layers of parenchymatous tissue
(iv) Endodermis	Absent	One layered, starchy sheath which is usually not well differentiated
(v) Pericycle	Absent	Made up of 1 or more layers of parenchymatous and sclerenchymatous cells
(vi) Medullary rays	Absent	Found in between vascular bundles
(vii) Pith (Medulla)	Absent	Abundant, made up of parenchymatous cells situated in the centre of stem
(viii) Vascular bundles	Scattered Conjoint, Collateral and closed. Larger towards centre Oval Bundle sheath present. Phloem parenchyma absent. Xylem vessels either Y or V shaped	Vascular bundles in a ring Conjoint, collateral and open All of same size Usually wedge-shaped. Bundle sheath absent. Phloem parenchyma present. Xylem vessels more radial

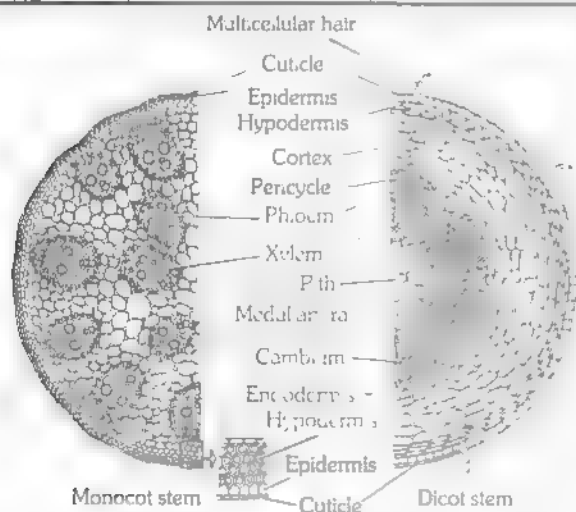


Fig : 2.2-14 Comparison of the T.S. of monocot and dicot stem

Table : 2.2-6 Difference between dicot and monocot root

Character	Dicot Root	Monocot Root
(i) Pericycle	Gives rise to secondary roots and lateral meristem	Gives rise to lateral roots only
(ii) Vascular bundles	Diarch to hexarch	Hexarch to polyarch (It is more than 6 in number)
(iii) Cambium	Develops at the time of secondary growth	Absent
(iv) Pith	Absent or poorly developed	Abundant and fully developed
(v) Secondary growth	Takes place	Does not take place
(vi) Cortex and Endodermis	Narrow cortex. Endodermis is less thickened and Casparian strips are more prominent	Cortex wide. Casparian strips are visible only in young root. Later on endodermal cells become highly thickened

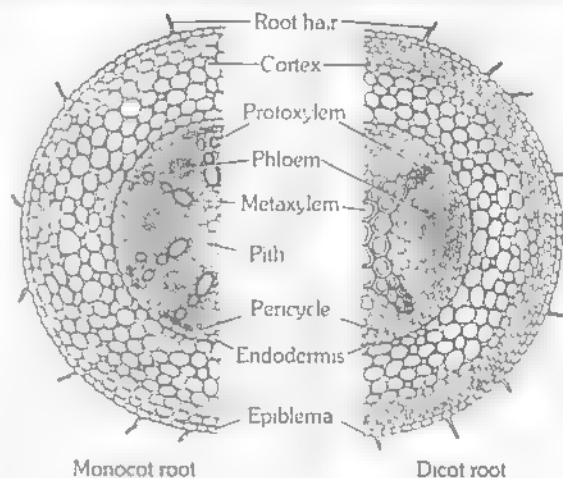


Fig : 2.2-15 Comparison of the T.S. of monocot and dicot root

## Secondary growth

The increase in thickness or girth due to the activity of the cambium and the cork cambium is known as secondary growth.

(1) **Secondary growth in stem :** On the basis of the activities of cambium and cork-cambium, secondary growth in stem can be discussed under the following heads :

**Activity of cambium :** The vascular cambium in between xylem and phloem is called intrafascicular or fascicular cambium which is primary in origin. At the time of secondary growth the parenchymatous cells of medullary rays between the vascular bundles become meristematic and form strip of cambium called as interfascicular cambium which is secondary in origin. Both inter and intrafascicular cambium joins together and form cambium ring which is partly primary and partly secondary in origin. By anticlinal divisions the circumference of the cambium increase. By periclinal division cambium produces the secondary xylem and phloem tissues on innerside and outside. The amount of sec xylem produced is 8-10 times greater than sec. phloem. Cambium cells are rectangular, thin walled, full of protoplasm and having meristematic activity. The cambium has two types of cells.

**The fusiform initials :** Which are elongated and form fibres, sieve cells, sieve tubes, tracheids

**Ray initials :** Which produce parenchyma cells of the rays in wood and phloem. Certain cells of cambium form some narrow bands of living parenchyma cells passing through secondary xylem and secondary phloem and are called secondary medullary rays. These provide radial conduction of food from the phloem, and water and mineral salts from the xylem

**Annual rings :** Activity of cambium is not uniform in those plants which grow in the regions where favourable climatic conditions (spring or rainy season) alternate regularly with unfavourable climatic conditions (cold water or dry hot summer). In temperate climates, cambium becomes more active in spring and forms greater number of vessels with wider cavities; while in winter it becomes less active and forms narrower and smaller vessels. The wood formed in the spring is known as spring wood and that formed in the dry summer or cold winter autumn wood or late wood. Both autumn and spring wood constitute a growth or annual ring. In one year only one growth ring is formed. Spring wood is light in colour while autumn wood is dark in colour.

**Activity of cork cambium :** Cork cambium or phellogen develops from outer layer of cortex. It produces secondary cortex or phelloderm on innerside and cork or phellem on outside. The cells of phellem are dead, suberized and impervious to water. Cells of phelloderm are thin walled, living and store food. Phellem, phellogen and phelloderm are collectively called as periderm. Periderm is secondary protective tissue. Due to pressure of secondary xylem, epidermis ruptures and cortex is largely lost after two or three years of secondary growth.

**Bark :** All dead tissues lying outside the active cork-cambium are collectively known as bark. This includes ruptured epidermis, hypodermis and cork. When cork-cambium appears in the form of a complete ring, it is known as ring bark, e.g., *Betula* (Bhojpatra). If the cork cambium occurs as separate strips and the resulting bark appears in the form of scales, such a bark is known as scaly bark. e.g., *Eucalyptus*, *Psidium guava*. The outermost layer of bark is dead and called as rhytidome

**Lenticels :** These are aerating pores formed in the cork through which gaseous exchange takes place. They are formed as a result of the action of phellogen. A lenticel appears as a scar or protrusion on the surface of the stem and consists of a radial row of thin-walled cells, known as complementary cells or filling tissue. They are found in old dicot stem, main function is gas exchange.

**Cork :** It consists of dead cells with thick walls heavily impregnated with suberin. These cells are compactly arranged in radial rows without intercellular spaces. Cork is impervious to water and prevents its loss from the plant surface. It also protects the inner tissues from the attack of fungi and insects. There is no differentiation of bark, sap wood and heart wood of Date palm. Commercial cork is obtained from *Quercus suber* (Oak)

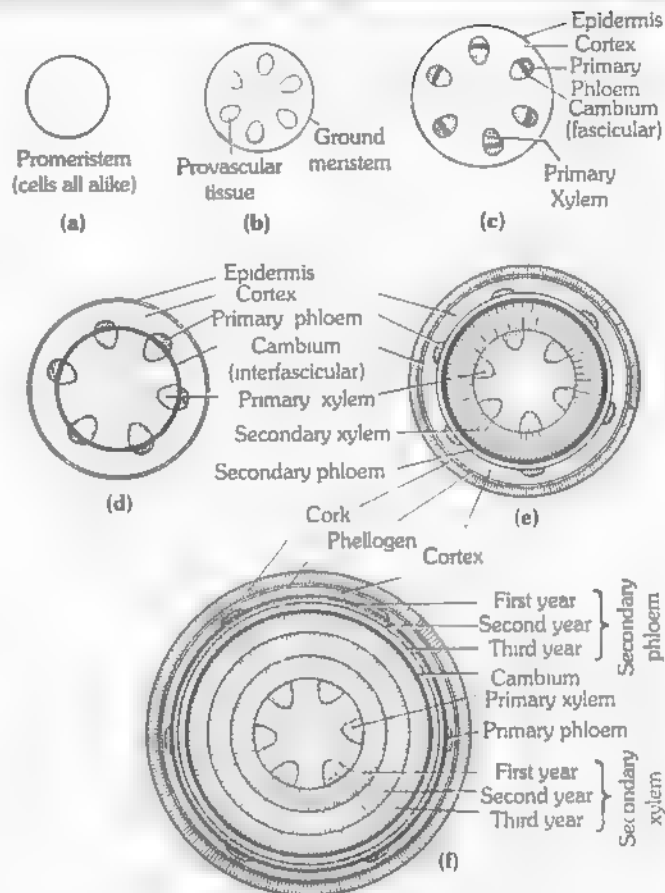


Fig : 2.2-16 Stages of secondary growth in stem

**Heart wood and sap wood :** In old trees, secondary wood is differentiated into a centrally situated darker and harder wood called the heart wood or duramen which are physiologically inactive (almost dead) and an outer light coloured zone called the sap wood or alburnum which are physiologically active. Dark colour of heart wood is due to the deposition of tannins, resins, gums, essential oils, etc. in the cell walls and cell cavities. The water conduction takes place through sap wood. During the conversion of sap wood into heartwood the most important change is development of tyloses in the heart wood. Tyloses are balloon like

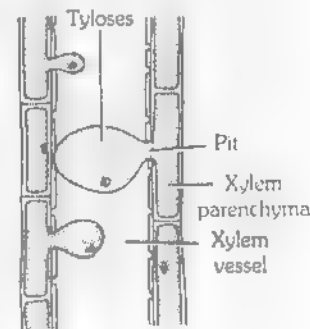


Fig : 2.2-17 Tyloses in xylem vessels

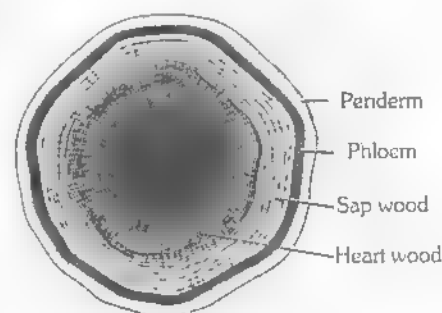


Fig : 2.2-18 T.S. of old dicot stem showing heart wood and sap wood



structures, develop from xylem parenchyma. These tyloses block the passage of xylem vessels so also called as tracheal plug. The heart wood is commercially used as wood. When the plant is made hollow, it will not die because the water conduction takes place through sap wood. The heart wood is well developed in *Morus alba* (Mulberry). The heart wood is absent in *Populus* and *Salix* plant. As a tree grows older thickness of heartwood increases and sap wood remains same.

(2) **Secondary growth in dicot roots** : Vascular bundles in dicot roots are radial, exarch and mostly triarch. Vascular cambium is formed secondarily from conjunctive parenchyma cells lying just

below each phloem strand. Thus the number of cambium strips form equal the number of phloem strands. The cells of pericycle lying outside the protoxylem also become meristematic to form part of strips of cambium. These cambial strips join the first formed cambium strips to form complete but wavy ring of vascular cambium. This cambium ring produces secondary xylem on inner side and secondary phloem on outer side. In roots, the growth rings are not distinct because there is no seasonal variation under the soil. From the outer layers of pericycle arises the phellogen which cuts phellem (cork) on the outer side and secondary cortex or phelloderm toward the inner side.

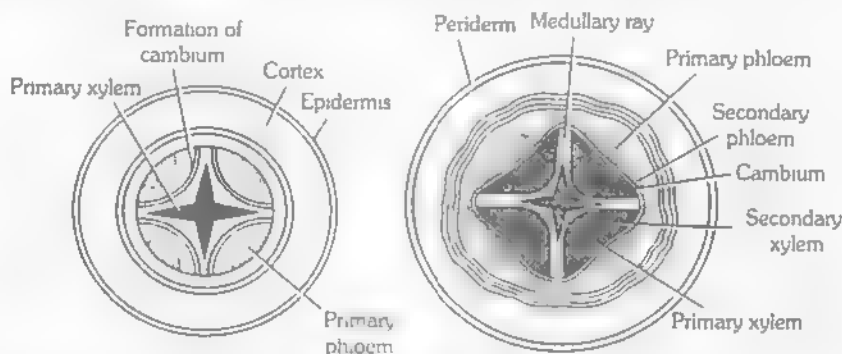


Fig : 2.2-19 Secondary growth in dicot

## Tips & Tricks

✚ N.Grew is the father of anatomy (1682) and coined the term tissue and parenchyma.

✚ Haberlandt (1914) proposed the names of protoderm (for dermatogen), ground meristem (for periblem) and procambium (for plerome)

✚ Haberlandt (1914) gave the terms Leptome for soft walled conducting part of phloem and hadrome for conducting part (tracheary elements) of xylem.

✚ Strasburger discovered albuminous cells instead of companion cells in the phloem of non-flowering plants

✚ In sugarcane there is no distinction of tunica and corpus

✚ In the roots the meristem is subterminal due to the presence of terminal cap.

✚ Reproductive apex is elongated in *Sagittaria* but it can be 400 times broad in *Chrysanthemum*.

✚ Sieve cells or sieve tube elements resemble RBCs in being without nucleus in the mature state

✚ The wood of *Tectona grandis* is termite resistant

✚ Cavities are of three types :

(1) Schizogenous : They are formed by enlargement of intercellular spaces or separation of cells e.g., oil cavities of Sunflower

(2) Lysigenous : They are formed by degeneration of cells, e.g., oil cavity of Citrus and protoxylem lacunae or water cavity in monocot stem vascular bundles

(3) Schizolysigenous : They are formed partly by separation and partly by degeneration of cells. e.g., protoxylem cavity.

✚ Pith cavity often present in monocot stems (e.g., grass) and occasionally in dicot stems (e.g., *Ricinus*).

✚ Wood without vessels is called homoxylous, e.g., Ranales (winteraceae, tetracentraceae, trochodendraceae). Whereas with vessels is called heteroxylous.

✚ The bottle cork is prepared from cork of *Quercus suber* (Oak tree)

✚ Lightest wood is of *Ochroma pyramidate* (*O. lagopus*).

✚ Heaviest wood is of *Guaiacum officinale*. In India heaviest wood is of *Acacia sundra*

✚ Most durable soft wood is of *Cedrus deodara*.

✚ Reaction wood is a wood formed in bending stems. When reaction wood is formed on the lower side, it is called as Compression wood e.g., conifers. When it is formed on the upper side, it is called as tension wood e.g., Dicots.

✚ Wound periderm is similar to natural periderm. But it is restricted to the place of injury and is used in producing the commercial cork.

✚ Maceration is a method of separation of various tissues by disintegration of middle lamella

✚ In some plants primary structure is abnormal such as presence of medullary bundles in pith e.g., *Boerhaavia*, *Mirabilis*, *Achyranthes*, *Bougainvillea* or presence of cortical vascular bundles (inverted) e.g., *Casuarina* and *Nyctanthus*.

✚ A protective tissue found in roots of some plants (Rosaceae, Myrtaceae) having alternate layers of endodermal and parenchyma cells are called periderm.

✚ Knots are the bases, scars/wounds of fallen branches which get covered by growth of secondary tissues. They form knots in the wood

✎ Abscission layer is a special layer of parenchymatous cells, appears at the base. Abscission is premature fall of plant parts from the plant without causing the injury. A protective layer of suberised thick walled cork cells is formed below the abscission layer to prevent infection or dessication (sometimes it is corky layer).

✎ Metaxylem consists of two larger and rounded vessels situated on the sides with the pitted tracheids in between them.

✎ Protoxylem consists of two smaller vessels situated towards the centre. The vessels of metaxylem are pitted and those of protoxylem are annular and spiral.

✎ Depending upon the relative position of protoxylem; xylem is of four types :

- (1) Exarch : Protoxylem towards the outside.
- (2) Endarch : Protoxylem towards innerside of metaxylem
- (3) Mesarch : Protoxylem surrounded by metaxylem.
- (4) Centrach : Protoxylem in the centre of metaxylem.

✎ Endarch xylem is also called centrifugal as xylem matures from inside to outside. Similarly, exarch xylem is known as centripetal because differentiation of xylem proceeds from outside to inside e.g. roots.

✎ Root hairs are found in zone of maturation.

✎ In the leaf, vascular bundles are found in the veins.

✎ An example of monocots showing secondary growth in stems is *Yucca* or *Draceana*

✎ Safranin stains lignified elements of the tissue.

✎ The longitudinal section of a root have four zones which occur in the following order (from the tip upward) : Root cap, cell division, cell enlargement, cell maturation.

✎ Sequence of secondary tissues from outside : Cork → Cork cambium → Secondary cortex → Primary phloem → Older secondary phloem → Younger secondary phloem → Cambium → Younger secondary xylem → Older secondary xylem → Primary xylem → Pith

## Ordinary Thinking

### Objective Questions

#### Tissue (General)

1. A group of cells alike in form, function and origin is called [NCERT; CMC Vellore 1994; MP PMT 1999]
  - (a) Organ
  - (b) Organelle
  - (c) Tissue
  - (d) None of these
2. Shoot apical meristem is found on the tip of [Odisha JEE 2008]
  - (a) Plumule
  - (b) Radicle
  - (c) Root
  - (d) Apex
3. Companion cells are closely associated with [NCERT; CBSE PMT (Pre.) 2012; WB-JEE 2016]
 

Or

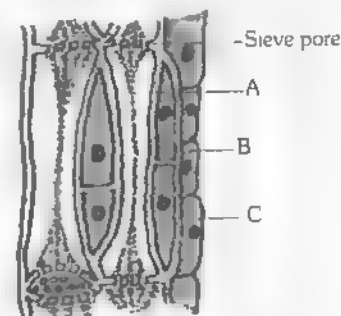
Transport of food material in higher plants takes place through [CBSE PMT (Mains) 2010]

  - (a) Sieve elements
  - (b) Vessel elements
  - (c) Trichomes
  - (d) Guard cells

4. Tunica corpus theory was proposed by [MP PMT 2001]
  - (a) Schmidt
  - (b) Strasburger
  - (c) Nageli
  - (d) Hofmeister
5. Histogen theory was proposed by [RPMT 1995]
  - (a) Bailey
  - (b) Haberlandt
  - (c) Hanstein
  - (d) Schmidt
6. Parenchymatous cells filling the space between dermal and vascular tissue is [Odisha JEE 2008]
  - (a) Ground tissue
  - (b) Epidermal tissue
  - (c) Pith
  - (d) Vascular bundles
7. Tracheids differ from other tracheary elements in [CBSE PMT 2014]
  - (a) Lacking nucleus
  - (b) Being lignified
  - (c) Having casparian strips
  - (d) Being imperforate
8. Parenchyma is
  - (a) A fundamental tissue physiologically and morphologically
  - (b) A fundamental tissue phylogenetically
  - (c) Progenitor of all specialised tissues
  - (d) All of the above
9. Which of the following statements is/are true
  - (A) Uneven thickening of cell wall is characteristic of sclerenchyma
  - (B) Periblem forms the cortex of the stem and the root
  - (C) Tracheids are the chief water transporting elements in gymnosperms
  - (D) Companion cell is devoid of nucleus at maturity
  - (E) The Commercial cork is obtained from *Quercus suber*

[Kerala PMT 2008]

  - (a) A and D only
  - (b) B and E only
  - (c) C and D only
  - (d) A, B and C only
  - (e) B, C and E only
10. Specialised parenchyma cells which store tannins, oils and crystals of calcium oxalate are called
  - (a) Sclereids
  - (b) Idioblasts
  - (c) Stone cells
  - (d) Conjunctive tissue
11. See the following figures and identify the types of simple tissue marked by alphabets [NCERT]



- (a) A – Sieve tube, B – Companion cell, C – Phloem parenchyma
- (b) A – Sieve tube, B – Phloem parenchyma, C – Phloem fibre
- (c) A – Vessel, B – Xylem parenchyma, C – Companion cell
- (d) A – Sieve tube, B – Phloem parenchyma, C – Companion cell

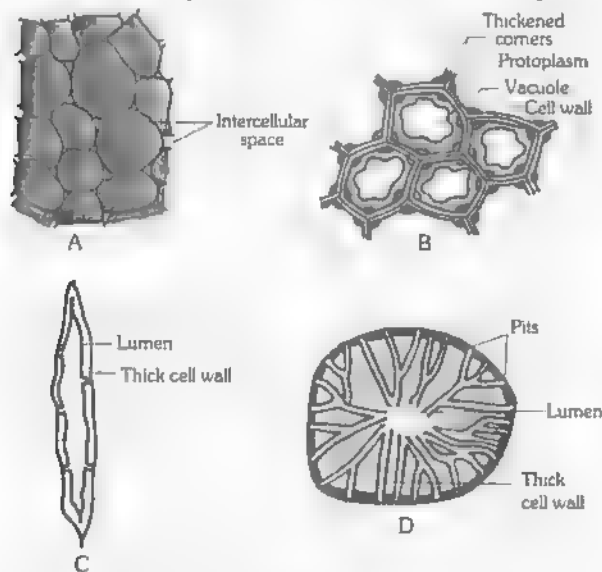
12. A simple mechanical tissue devoid of lignin is

Or

Which one of the following is an effective tissue of growing organs with sufficient elasticity

- (a) Parenchyma (b) Collenchyma  
(c) Sclerenchyma (d) Chlorenchyma

13. See the following figures and identify the types of simple tissue indicated by A, B, C and D [NCERT]



- (a) A - Collenchyma, B - Parenchyma, C - Sclereid (Sclerenchyma), D - Fibre (Sclerenchyma)  
(b) A - Parenchyma, B - Collenchyma, C - Sclereid (Sclerenchyma), D - Fibre (Sclerenchyma)  
(c) A - Collenchyma, B - Parenchyma, C - Fibre (Sclerenchyma), D - Sclereid (Sclerenchyma)  
(d) A - Parenchyma, B - Collenchyma, C - Fibre (Sclerenchyma), D - Sclereid (Sclerenchyma)

14. A mature sieve tube differs from vessel in

- (a) Being nearly dead  
(b) Lacking cytoplasm  
(c) Lacking a functional nucleus  
(d) Absence of lignified walls

15. From evolutionary point of view, tracheids and sieve cells are more primitive than tracheae and sieve tubes respectively. The angiosperms have [EAMCET 2009]

- (a) Tracheae and sieve tubes  
(b) Tracheids, tracheae and sieve tubes  
(c) Tracheids, sieve cells and sieve tubes  
(d) Tracheids, tracheae and sieve cells

16. In pteridophyta and gymnosperms which cells are present in place of companion cell

- (a) Sclereids (b) Albuminous cells  
(c) Idioblasts (d) None of the above

17. Wood is a common name of

[J & K CET 2002; MP PMT 2004, 05]

- (a) Phloem (b) Secondary xylem  
(c) Cambium (d) Vascular bundles

18. At maturity the sieve plates become impregnated with

[Kerala PMT 2009]

- (a) Cellulose (b) Pectin  
(c) Suberin (d) Lignin  
(e) Callose

19. Consider the following statements and choose the correct option

- (i) The thread like cytoplasmic strands, running from one cell to other is known as plasmodesmata  
(ii) Xylem and phloem constitute the vascular bundle of the stem  
(iii) The first form xylem elements are described as metaxylem  
(iv) Radial vascular bundles are mainly found in the leaves

[Kerala PMT 2009]

- (a) (i) is true, but (ii), (iii) and (iv) are wrong  
(b) (ii) is true, but (i), (iii) and (iv) are wrong  
(c) (iii) is true, but (i), (ii) and (iv) are wrong  
(d) (iv) is true, but (i), (ii) and (iii) are wrong  
(e) (i) and (ii) are true, but (iii) and (iv) are wrong

20. Which of the following statement is true [Kerala PMT 2010]

- (a) The collenchyma occurs in layers below the epidermis in monocotyledonous plants  
(b) Sclerenchyma cells are usually dead and without protoplasts  
(c) Xylem parenchyma cells are living and thin walled and their cell walls are made up of lignin  
(d) The companion cells are specialized sclerenchymatous cells  
(e) Phloem fibres are generally present in the primary phloem

21. Intraxylary phloem may also be called

- (a) Internal phloem (b) Included phloem  
(c) Vestigial phloem (d) None of the above

22. Interfascicular cambium develops from the cells of

[NCERT; NEET 2013]

- (a) Pericycle (b) Medullary rays  
(c) Xylem parenchyma (d) Endodermis

23. Active division takes place in the cells of [MP PMT 1998]

- (a) Xylem (b) Phloem  
(c) Cambium (d) Sclerenchyma

24. The only plant cells without nuclei among the following are

[NCERT; CPMT 1998, 2009; KCET 1999, 2001; RPMT 2002]

Or

The tissue which is living but does not possess nucleus in mature stage is [RPMT 1995; CBSE PMT 1997; BHU 2008]

- (a) Cambium cells (b) Cells of pericycle  
(c) Xylem parenchyma (d) Sieve tubes

25. Cork tissue arises from [AFMC 2005]

- (a) Periderm (b) Phellogen  
(c) Pelloderm (d) Phellem

26. Collenchyma differs from sclerenchyma

- (a) Retaining protoplasm at maturity  
(b) Having thick walls  
(c) Having wide lumen  
(d) Being meristematic

27. Walls of sclerenchyma are  
(a) Rigid (b) Lignified  
(c) Pectinised (d) Suberised
28. Tunica corpus theory is related with [Odisha JEE 2009]  
(a) Root apex  
(b) Lateral meristems  
(c) Root cap  
(d) Shoot apex (apical meristem)
29. The balloon like outgrowth of parenchyma in the lumen of a vessel is known as [BHU 1994; NEET (Phase-II) 2016]  
(a) Histogen (b) Tyloses  
(c) Phellogen (d) Tunica
30. Vessels differ from tracheids [MHCET 2011]  
(a) In being derived from single cell  
(b) In having vertical rows of cells with dissolved cross walls  
(c) In being living  
(d) They help in the conduction of water
31. Vascular cambium and cork cambium are examples of [CBSE PMT 1990; AIIMS 1999; J & K CET 2002; KCET 2009]  
(a) Lateral meristem  
(b) Apical meristem  
(c) Elements of xylem and phloem  
(d) Intercalary meristem
32. Laticiferous vessels instead of laticiferous cells are found in  
(a) *Ficus* (b) *Calotropis*  
(c) *Poppy* (d) *Nerium*
33. The histogen layer present at the apex of the root tip is called [BHU 2008]  
(a) Dermatogen (b) Procambium  
(c) Calypotrogen (d) Plerome
34. Radial conduction of water takes place by [AMU (Med.) 2012]  
(a) Vessels (b) Vessels and tracheids  
(c) Phloem (d) Ray parenchyma cells
35. Sieve tubes are better suited for translocation, because [NCERT]  
(a) Possess broader lumen and perforated cross walls  
(b) Are broader than long  
(c) Possess bordered pits  
(d) Possess no end walls
36. Collenchyma differs from parenchyma in having  
(a) Living protoplasm (b) Cellulose walls  
(c) Vacuoles (d) Pectin deposits at corners
37. Cystoliths sometimes deposited in plant cells are crystals of (aggregation of) [AIIMS 1999; BVP 2004; RPMT 2006; MP PMT 2010; Odisha JEE 2010]  
(a) Calcium oxalate (b) Calcium carbonate  
(c) Magnesium carbonate (d) Glucosides
38. Trachea, tracheids, wood fibres and parenchyma tissues are found in [CPMT 2003]  
(a) Xylem (b) Phloem  
(c) Cambium (d) Cortex
39. In the following pairs where do you get lignin in both the element [WB JEE 2008]  
(a) Tracheid and Collenchyma  
(b) Sclerenchyma and sieve tube  
(c) Sclerenchyma and trachea  
(d) Parenchyma and endodermis
40. Tyloses are [BHU 1995, 2000]  
(a) Wound healing secretions  
(b) Responsible for plugging the lumen of vessels  
(c) Special epidermal hairs covering stomata in xerophytes  
(d) Callus secretion on sieve plates
41. Plant tissues, which are actively growing have water content of  
(a) 40 – 50% (b) 65 – 75%  
(c) 20 – 40% (d) 85 – 95%
42. A component of xylem is [MP PMT 1999]  
(a) Sieve tube (b) Medullary ray  
(c) Sclereids (d) Tracheid
43. Which of the following supporting tissues have cells with unequally thickened walls  
(a) Fibres (b) Sclereids  
(c) Collenchyma (d) All the above
44. A common structural feature of vessel elements and sieve tube elements is [CBSE PMT 2006]  
(a) Presence of p-protein (b) Enucleate condition  
(c) Thick secondary walls (d) Pores on lateral walls
45. Vessels are absent in  
(a) Teak wood (b) Shisham wood  
(c) Chir wood (d) Sal wood
46. All the following statements regarding sieve tube elements are true except [Kerala PMT 2007]  
(a) Their end walls have perforated sieve plates which become impregnated with lignin at maturity  
(b) They possess a peripheral cytoplasm as well as a large vacuole  
(c) Distinct proteinaceous inclusions, the P-proteins are seen evenly distributed throughout the lumen  
(d) Long, slender, tube-like structures arranged in longitudinal series  
(e) They are devoid of nucleus at maturity
47. Xylem fibre is  
(a) Bast fibre (b) Wood fibre  
(c) Heart wood (d) Libriform fibre
48. The casparian strips of root endoderm contain a mixture of [CBSE PMT 1994; BHU 1994; HP PMT 2005; Kerala PMT 2008]  
(a) Cellulose and cutin (b) Cellulose and lignin  
(c) Lignin and suberin (d) Cellulose and suberin
49. Parenchymatous cells are found in [Manipal 2005]  
(a) Pulp of fruit (b) Seeds  
(c) Endocarp (d) Skin of fruit
50. Meristematic cells have [Manipal 2005]  
(a) Thick cell wall and large intercellular spaces  
(b) Thick cell wall and no intercellular space  
(c) Thin cell wall and large intercellular spaces  
(d) Thin cell wall and no intercellular spaces

51. The root apex is subterminal because it  
[NCERT; Kashmir MEE 1995]  
(a) Is covered by tunica cells (b) Is covered by root hairs  
(c) Has many corpus cells (d) Is covered by root cap
52. Root cap in dicots is formed from  
(a) Protoderm (b) Ground meristem  
(c) Calyptragen (d) Procambium
53. One of the characteristic of sieve tube is [WB JEE 2008]  
(a) It is a part of phloem  
(b) Function is transport of inorganic solutes  
(c) It is dead cell  
(d) Sieve plate is not present
54. Interfascicular cambium is a [WB JEE 2010]  
(a) Primary meristematic tissue  
(b) Primordial meristem  
(c) Type of protoderm  
(d) Secondary meristematic tissue
55. Which of the following is a complex tissue [CPMT 2010]  
(a) Parenchyma (b) Collenchyma  
(c) Xylem (d) Sclerenchyma
56. Safranin stains which elements of the tissue  
(a) Starch elements (b) Lignified elements  
(c) Protein elements (d) Hard bast
57. Laticiferous vessels are found in [CPMT 1993]  
(a) Xylem tissue (b) Phloem tissue  
(c) Cortex (d) None of the above
58. Term 'Leptome' is a synonym of  
(a) Companion cells (b) Sieve elements  
(c) Phloem fibres (d) Phloem parenchyma
59. The calyptragen of the root apex forms [MP PMT 2003]  
(a) Rhizoids (b) Root nodule  
(c) Root hairs (d) Root cap
60. Histogen theory is more applicable for [CPMT 1999]  
(a) Root apex (b) Shoot apex  
(c) Meristematic tissue (d) None of these
61. Meristematic tissue in vascular bundle is [MP PMT 2007]  
(a) Phellem (b) Procambium  
(c) Interfascicular cambium (d) Fascicular cambium
62. In which of the following phloem parenchyma is absent  
(a) Maize (b) Sunflower  
(c) Guava (d) Banyan
63. Meristematic tissue responsible for increase in girth of tree trunk is [RPMT 2002; NEET (Karnataka) 2013]  
(a) Lateral meristem (b) Intercalary meristem  
(c) Primary meristem (d) Apical meristem
64. Function of storage is performed by [BHU 1999]  
(a) Parenchyma (b) Sclerenchyma  
(c) Phloem (d) All the above
65. On the basis of origin, meristematic tissues can be classified under how many groups  
(a) 2 (b) 3  
(c) 4 (d) 5
66. Which of the following are primary meristems  
(a) Pleurome (b) Protoderm  
(c) Intercalary meristem (d) All the above
67. Collenchymatous tissue is found in [CBSE PMT 1990]  
(a) Climbing plants  
(b) Aquatic plants  
(c) Woody climbers  
(d) Herbaceous climbers
68. Parenchymatous tissue is characterised by the [JIPMER 2002; MP PMT 2004]  
(a) Presence of uniform thickening  
(b) Presence of thickening in the corners  
(c) Presence of intercellular spaces  
(d) Presence of lignified walls
69. The histogens are classified on the basis [Manipal 2005]  
(a) Cells they contain  
(b) Cells they give rise to future tissue  
(c) Meristematic activity  
(d) Cell division
70. Which of the following are simple tissues [CPMT 2000]  
(a) Parenchyma, xylem and phloem  
(b) Parenchyma, collenchyma and sclerenchyma  
(c) Parenchyma, xylem and collenchyma  
(d) Parenchyma, xylem and sclerenchyma
71. Bordered pits are found in  
(a) Phloem (b) Protoxylem  
(c) Metaxylem (d) Pith
72. The plant tissues commonly found in fruit walls of nuts and pulp of some fruits like guava are termed as [NCERT; AMU (Med.) 2009]  
Or  
Pear fruits are gritty due to the presence of [J & K CET 2012]  
Or  
Tissue composed of non-parenchymatous cells and have isodiametric or irregular shape is called  
(a) Fibres (b) Tracheids  
(c) Sclereids (d) Vessels
73. Promeristem gives rise to which meristem [MP PMT 1997]  
(a) Secondary (b) Lateral  
(c) Primary (d) Apical
74. Starch sheath is another name of [AMU (Med.) 2009]  
(a) Hypodermis (b) Epidermis  
(c) Casparian strip (d) None of these
75. Sieve tubes have  
(a) Apical and oblique septa  
(b) Perforated and longitudinal septa  
(c) Perforated and oblique septa  
(d) Simple oblique wall
76. Which one of the following statements pertaining to plant structure is correct [AIIMS 2005]  
(a) Cork have no stomata, but lenticels carry out transpiration  
(b) Passage cells help in transfer of food from cortex to phloem  
(c) Sieve tube elements possess cytoplasm but not nuclei  
(d) The shoot apical meristem has a quiescent centre

77. 'Protoderm' and 'procambium' terms were coined by  
(a) Haberlandt (b) Hanstein  
(c) Schmidt (d) Nageli
78. Which of the following tissues consist of living cells  
[MP PMT 2009]  
(a) Vessels (b) Tracheids  
(c) Companion cell (d) Sclerenchyma
79. Tyloses thickenings are seen in [CPMT 2001]  
(a) Phloem cells  
(b) Ray parenchyma only  
(c) Collenchyma  
(d) Ray parenchyma and xylem cells
80. Name the tissue from which procambium and primary structures of plant originates  
(a) Phellogen (b) Promeristem  
(c) Calyptragen (d) None of these
81. The function of a vessel is [BHU 1995; Pb. PMT 2004]  
(a) Conduction of food  
(b) Conduction of water and minerals  
(c) Conduction of hormones  
(d) All the above
82. The outermost primary meristem gives rise to [CPMT 2001]  
(a) Epidermis (b) Procambium  
(c) Ground meristem (d) All of the above
83. The long plants are capable of standing erect due to presence of [BHU 2012]  
(a) Sclerenchyma (b) Collenchyma  
(c) Parenchyma (d) Prosenchyma
84. Epiblema in roots is derived from [BHU 2002]  
(a) Protoderm (b) Procambium  
(c) Ground meristem (d) Calyptragen
85. In a woody dicotyledonous tree, which of the following parts wall mainly consist of primary tissues [CBSE PMT 2005]  
(a) Stem and root (b) All parts  
(c) Shoot tips and root tips (d) Flowers, fruits and leaves
86. Tunica differs from corpus in  
(a) Position (b) Rate of growth  
(c) Plane of division (d) Region of activity
87. Histogen theory states that epidermis is derived from the [AMU (Med.) 2006]  
(a) Periblem (b) Cambium  
(c) Cortex (d) Dermatogen
88. What is meristems [MP PMT 2005]  
(a) Dividing cells (b) Non dividing cells  
(c) Permanent cells (d) Complex tissues
89. Bordered pits are found in [CPMT 1993; BVP 2000]  
(a) Gymnosperms (b) Bryophytes  
(c) Monocots (d) Hydrilla
90. The tip of the root apical meristem is proceeded by root pocket in  
(a) Brassica (b) Eichhornia  
(c) Petunia (d) Wheat
91. Which one of the following pairs is an example for lateral meristem [CPMT 1998; KCET 2010]  
(a) Procambium and phelloderm  
(b) Interfascicular cambium and phellem  
(c) Phellogen and phelloderm  
(d) Phellogen and fascicular cambium
92. Match the followings in column I with column II and choose the correct combination
- |    | Column I         |    | Column II            |
|----|------------------|----|----------------------|
| A. | Xylem vessels    | 1. | Store food materials |
| B. | Xylem trachieds  | 2. | Obliterated lumen    |
| C. | Xylem fibre      | 3. | Perforated plates    |
| D. | Xylem parenchyma | 4. | Chisel-like ends     |
- [Kerala PMT 2006]  
(a) A-4, B-3, C-2, D-1 (b) A-3, B-2, C-1, D-4  
(c) A-2, B-1, C-4, D-3 (d) A-1, B-2, C-3, D-4  
(e) A-3, B-4, C-2, D-1
93. Bamboo and grasses elongate by the activity of ----- [KCET 2004]  
(a) Secondary meristem (b) Lateral meristem  
(c) Apical meristem (d) Intercalary meristem
94. Which is present in vascular bundles of gymnosperms [RPMT 1999]  
(a) Tracheids (b) Vessels  
(c) Companion cells (d) All of these
95. Root cap is absent in [BHU 1994, 99; RPMT 2002, 06; Manipal 2005; CPMT 2009]  
(a) Lithophytes (b) Hydrophytes  
(c) Xerophytes (d) Mesophytes
96. Axillary bud and terminal bud are derived from the activity of [NCERT; CBSE PMT 2002]  
(a) Parenchyma (b) Lateral meristem  
(c) Apical meristem (d) Intercalary meristem
97. Vessels are found in [CBSE PMT 2002]  
(a) All pteridophyta (b) All angiosperms  
(c) Some gymnosperm (d) Both (b) and (c)
98. The meristem of root is [MHCET 2001]  
(a) Apical (b) Sub apical  
(c) Intercalary (d) Lateral
99. Which one of the following is not a lateral meristem [NCERT; CBSE PMT (Pre.) 2010]  
(a) Intercalary meristem (b) Intrafascicular cambium  
(c) Interfascicular cambium (d) Phellogen
100. Lignin is the main constituent of [CPMT 1993]  
(a) Woody tissues (b) Growing tissues  
(c) Phloem (d) Cortex
101. Which of the following is absent in phloem of *Pinus* [BVP 2001]  
(a) Phloem parenchyma (b) Sieve cells  
(c) Companion cells (d) None of these
102. The plant which reproduces by apical meristem is [Manipal 2005]  
(a) Gymnosperm (b) Pteridophyte  
(c) Angiosperm (d) Algae

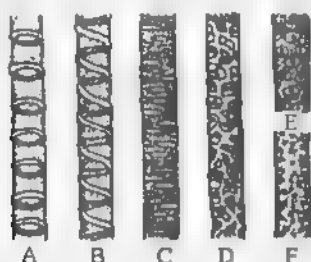
103. P – protein is found in [CPMT 2005]  
 (a) Collenchyma (b) Parenchyma  
 (c) Xylem (d) Sieve tube

104. Function of companion cells is [NCERT; MP PMT 1998, 2000; AIIMS 2004; CBSE PMT (Malna) 2011]  
 (a) Loading of sucrose into sieve elements by passive transport  
 (b) Loading of sucrose into sieve elements  
 (c) Providing energy to sieve elements for active transport  
 (d) Providing water to phloem

105. Companion cells are part of angiospermic [MHCET 2000; MP PMT 2010]  
 (a) Xylem (b) Phloem  
 (c) Pith (d) Collenchyma

106. Which of the following cell is totipotent [BHU 1999; CBSE PMT 1999; KCET 2000; AFMC 2000]  
 (a) Meristem (b) Sieve tube  
 (c) Collenchyma (d) Xylem vessel

107. The following diagrams show the types of secondary thickenings in the xylem vessels. Identify the types labelled from A to F. Choose the correct option from those given [KCET 2006]



- (a) A = spiral, B = annular, C = reticulate, D = scalariform, E = pitted with border, F = pitted simple  
 (b) A = annular, B = spiral, C = scalariform, D = reticulate, E = pitted with border, F = pitted simple  
 (c) A = annular, B = spiral, C = scalariform, D = reticulate, E = pitted simple, F = pitted with border  
 (d) A = spiral, B = annular, C = scalariform, D = reticulate, E = pitted with border, F = pitted simple
108. The xylem fibres are classified into  
 (a) Protoxylem and metaxylem  
 (b) Primary and secondary fibres  
 (c) Fibre tracheids and fibres  
 (d) Long and short fibres
109. The trees have in them a large amount of  
 (a) Starch (b) Lignocellulose  
 (c) Cellulose (d) Chitin
110. Meristems are found in  
 (a) *Cycas* stem (b) Fern leaf  
 (c) Pollens of *Pinus* (d) Fern rhizome
111. Rod shaped elongated sclereids found in the seed coats of pulses are known as  
 (a) Astrosclereids (b) Macrosclereids  
 (c) Trichosclereids (d) Brachysclereids
112. The process by which plants becomes woody is  
 (a) Impregnation (b) Lignification  
 (c) Fossilization (d) Calcification

113. Casparian strips are present in the \_\_\_\_\_ of the root [NCERT; KCET 2011]  
 (a) Epiblema (b) Cortex  
 (c) Pericycle (d) Endodermis

114. Promeristem is found in [JIPMER 1994]  
 (a) Embryo (b) Root apex  
 (c) Shoot apex (d) Intercalary region

115. Meristematic tissues include [AFMC 1994]  
 (a) Leaf tips, cork cambium and vascular cambium  
 (b) Stem and root apices, cork cambium and mature fruits  
 (c) Stem and root apices, vascular cambium and cork cambium  
 (d) Mature fruits and leaf tips

116. The complex tissues include [MP PMT 1993]  
 (a) Scleroids (b) Sclerenchyma  
 (c) Secretory tissues (d) Collenchyma

117. Which of the following elements has its end walls perforated [AIEEE Pharmacy 2004]  
 (a) Tracheid (b) Vessel  
 (c) Fiber (d) Scleried

118. Epidermis in stem is produced from [NCERT; BHU 2002]  
 (a) Protoderm (b) Procambium  
 (c) Ground meristem (d) Calyptragen

119. The tissue which perpetuates itself by active cell division is [Kerala PMT 2004]  
 (a) Permanent tissue (b) Ground tissue  
 (c) Meristematic tissue (d) Vascular tissue  
 (e) None of these

120. Vascular cambium of the root is an example of [BHU 2000; AIIMS 2000, 13]  
 (a) Apical meristem (b) Intercalary meristem  
 (c) Secondary meristem (d) Root apical meristem

121. Intercalary meristems are present in the  
 (a) Nodal region  
 (b) Internodal region  
 (c) Bryophytes  
 (d) Nodal region close to base of plant

122. Intercalary meristem is seen in  
 (a) Paddy (b) *Ficus*  
 (c) Cabbage (d) *Cucurbita*

123. Intercalary meristem results in [Kerala PMT 2004]  
 (a) Secondary growth (b) Primary growth  
 (c) Apical growth (d) Secondary thickening  
 (e) Secondary over growth

124. Chlorenchyma cells are chlorophyll containing  
 (a) Sclerenchyma cells (b) Epidermis  
 (c) Parenchyma (d) Phloem

125. The loosely arranged nonchlorophyllous parenchyma cells present in lenticels are called [KCET 2011]  
 (a) Complementary cells (b) Passage cells  
 (c) Water stomata (d) Albuminous cells

126. From which of the following tissue the protoderm is derived  
 (a) Procambium (b) Cambium  
 (c) Promeristem (d) All the above

127. In a longitudinal section of a root, starting from the tip upward, the four zones occur in the following order  
[CBSE PMT 2004]  
(a) Cell division, cell enlargement, cell maturation, root cap  
(b) Cell division, cell maturation, cell enlargement, root cap  
(c) Root cap, cell division, cell enlargement, cell maturation  
(d) Root cap, cell division, cell maturation, cell enlargement
128. Healing of wound in plants takes place by the activity of  
[CPMT 1998; CBSE PMT 2000; DPMT 2004]  
(a) Ground tissue (b) Callus deposition  
(c) Secondary meristem (d) Permanent tissue
129. Which of the following statement is true about parenchymatous cells  
[MP PMT 2006]  
(a) Presence of thickening at corner  
(b) Presence of uniform thickening  
(c) Presence of intercellular space  
(d) Presence of lignified wall
130. Lateral meristem is responsible for  
[MP PMT 2004]  
(a) Growth in length (b) Growth in parenchyma  
(c) Growth in thickness (d) Growth in cortex
131. The commercial jute fibres are obtained from  
[MP PMT 2004]  
(a) Interxylary fibres (b) Xylem fibers  
(c) Phloem fibers (d) None of these
132. Root cap is not found in  
(a) Hollyhock (b) *Pistia*  
(c) Sunflower (d) China rose
133. Lignin is the important constituent in the cell wall of  
[MP PMT 1994, 98, 2002]  
(a) Phloem (b) Parenchyma  
(c) Xylem (d) Cambium
134. Which of the following is absent in the primary and secondary structure of stem of *Pinus*  
[AIIMS 2000]  
(a) Sieve tubes (b) Mucilage duct  
(c) Companion cells (d) Phloem parenchyma
135. Xylem position in secondary xylem is  
[RPMT 1995]  
(a) Exarch (b) Endarch  
(c) Mesarch (d) None of these
136. Dead cells of root are supplied by  
[RPMT 1995]  
(a) Calyptragen (b) Protoderm  
(c) Phallogen (d) Dermatogen
137. Quiescent centre is found in  
[CPMT 1993, 2002, 05; RPMT 2005, 06; WB JEE 2010]  
(a) Stem tip (b) Root tip  
(c) Leaf tip (d) None of these
138. The fibres associated with phloem are known as  
[MP PMT 2006]  
(a) Wood fibre (b) Surface fibre  
(c) Bast fibre (d) Hard fibre
139. The cell wall of xylem cells is rich in  
[MP PMT 1995]  
(a) Lipid (b) Protein  
(c) Lignin (d) Starch
140. Porous wood contains mainly  
[AIIMS 2001]  
(a) Fibres (b) Vessels  
(c) Trachieds (d) Solid secretions
141. Conducting part of phloem according to Haberlandt (1914) is  
[J & K CET 2002]  
(a) Hadrome (b) Leptome  
(c) Sterom (d) Bark
142. The difference in phloem of gymnosperms and angiosperms is due to  
[RPMT 2002, 06]  
(a) Parenchyma (b) Sieve cell  
(c) Companion cell (d) Fibres
143. Starch is mainly manufacture by  
[JIPMER 2002]  
(a) Palisade parenchyma (b) Spongy parenchyma  
(c) Guard cells (d) Vascular bundle
144. Fibres are obtained from  
[BHU 1994; JIPMER 2002]  
(a) Xylem, phloem and sclerenchyma  
(b) Xylem, phloem, sclerenchyma and epidermis  
(c) Xylem, parenchyma, epidermis  
(d) Xylem, parenchyma, endodermis
145. Aerenchyma is formed in the tissue of  
[MP PMT 1997]  
(a) Sclerenchyma (b) Parenchyma  
(c) Phloem (d) None of the above
146. The chief water conducting elements of xylem in gymnosperms are  
[CBSE PMT (Pre.) 2010]  
(a) Tracheids (b) Vessels  
(c) Fibres (d) Transfusion tissue
147. Which tissue makes up the embryo of a seed  
(a) Meristematic tissue (b) Permanent parenchyma  
(c) Collenchyma (d) Sclerenchyma
148. The meristem which develops into a primary vascular tissue is  
[MP PMT 1999; Odisha JEE 2008; WB JEE 2009]  
Or  
Portion of apical meristem that gives rise to xylem tissue is called  
[WB JEE 2012]  
(a) Protonema (b) Promeristem  
(c) Ground meristem (d) Procambium
149. Tracheids differs from vessels in having  
[RPMT 2006]  
(a) Thick wall  
(b) Bordered pits  
(c) Discontinuous intercalary wall  
(d) Spiral thickening
150. Hard lignified thick walled long and pointed cells a plant are  
[MP PMT 1999]  
(a) Parenchyma (b) Sclerenchyma  
(c) Collenchyma (d) Sclereids
151. Which tissue is derived from tunica  
(a) Epidermis (b) Endodermis  
(c) Pericycle (d) Vascular tissue
152. Which of the following plants grow by a single "apical cell"  
(a) Monocots (b) Dicots  
(c) Gymnosperms (d) Bryophytes
153. Which structure is not found in the leaves of a bean plant  
(a) Guard cell (b) Chloroplast  
(c) Phloem (d) Lenticel
154. Histogens are component of or The histogens are differentiated in  
(a) Apical meristem (b) Intercalary meristem  
(c) Lateral meristem (d) Secondary meristem
155. How many histogens are present at the apex of root  
(a) 1 (b) 2  
(c) 3 (d) 4
156. The vascular cambium normally gives rise to  
[NEET 2017]  
(a) Phelloderm (b) Primary phloem  
(c) Secondary xylem (d) Periderm



## The tissue system

1. Star shaped stele devoid of pith termed as [Odisha JEE 2012]
  - (a) Actinostele (b) Solenostele
  - (c) Dictyostele (d) Plectostele
2. A stele with a central core of xylem surrounded by phloem is called or Actinostele is a modification of
 

Or

 Pith is absent in [Odisha JEE 2009; AFMC 2012]
  - (a) Protostele (b) Siphonostele
  - (c) Solenostele (d) Dictyostele
3. The arrangement of xylem in stem is [Odisha JEE 2010]
  - (a) Endarch (b) Exarch
  - (c) Mesarch (d) Both (a) and (b)
4. Reduction in vascular tissue mechanical tissue and cuticle is characteristic of [CBSE PMT 2009]
  - (a) Xerophytes (b) Mesophytes
  - (c) Epiphytes (d) Hydrophytes
5. The length of different internodes in a culm of sugarcane is variable because [CBSE PMT 2008]
  - (a) Size of leaf lamina at the node below each internode
  - (b) Intercalary meristem
  - (c) Shoot apical meristem
  - (d) Position of axillary buds
6. Vascular bundles in which phloem is found on both sides of xylem are called (In which of the following phloem occurs in two patches) [CBSE PMT 1992; BVP 2003]
  - (a) Collateral (b) Bicollateral
  - (c) Radial (d) Amphicribal
7. Amphivasal or leptocentric vascular bundles are found in
 

Or

 An example of monocots showing secondary growth in stems is
  - (a) *Cycas* and *Dryopteris* (b) *Dracaena* and *Yucca*
  - (c) *Helianthus* and *Cucurbita* (d) Maize and wheat
8. A root hair is formed by [IAMCET 1995]
  - (a) Epidermal cell (b) Endodermal cell
  - (c) Cortical cell (d) Pericycle cell
9. The layer of cells outside the phloem meant for giving rise to the root branches is called [Kerala CET 2003]
  - (a) Cambium (b) Carpus
  - (c) Endodermis (d) Pericycle
10. The root cap is not used in absorption of water due to [Odisha JEE 2011]
  - (a) Presence of root hairs
  - (b) Absence of root hairs
  - (c) Its presence in elongation zone
  - (d) None of these
11. In root, pericycle gives rise to
  - (a) Branch root and cork cambium
  - (b) Cortex and pith
  - (c) Epidermis and vascular bundles
  - (d) Xylem and phloem
12. Vascular bundles in the stem of *Cucurbita* or *Lagenaria* are [AIIMS 1992; KCET 1999; BHU 2001]
  - (a) Collateral (b) Bicollateral
  - (c) Radial (d) Inverted
13. Periblem gives rise to [MP PMT 2001; RPMT 2005]
  - (a) Pericycle (b) Cortex
  - (c) Medulla (d) Epidermis
14. Cuticle is secreted by [CPMT 2002]
  - (a) Epidermis (b) Endodermis
  - (c) Both (a) and (b) (d) Hypodermis
15. Vascular bundles are derived from (originate from)
  - (a) Dermatogen
  - (b) Periderm
  - (c) Endogenous tissue the procambial strand or plerome
  - (d) Cortex
16. The composition of stele is [Odisha JEE 2011]
  - (a) Pith, vascular bundle
  - (b) Pericycle, pith
  - (c) Endodermis, pericycle
  - (d) Endodermis, pericycle, pith
17. Bulliform or motor cells are present in
  - (a) Dicot stem
  - (b) Upper epidermis of dicot leaves
  - (c) Lower epidermis of monocot leaves
  - (d) Upper epidermis of monocot leaves
18. Ground tissue includes [NCERT; CBSE PMT (Pre.) 2011]
  - (a) All tissues internal to endodermis
  - (b) All tissues external to endodermis
  - (c) All tissues except epidermis and vascular bundles
  - (d) Epidermis and cortex
19. Radial vascular bundle can be seen in [CPMT 1996; MP PMT 2005]
  - (a) Leaf (b) Dicot root
  - (c) Stem (d) Flower
20. Water stomata are found in
  - (a) Plants inhabiting humid region
  - (b) Plants inhabiting dry regions
  - (c) All plants
  - (d) Plants lacking normal stomata
21. Raphides are found in [MP PMT 1996]
  - (a) *Citrus* (b) *Colocasia*
  - (c) *Nerium* (d) Mango
22. Mesarch xylem is common in [Pb. PMT 1999]
  - (a) Ferns (b) Bryophytes
  - (c) Dicots (d) Monocots
23. In plants like *Nymphaea* which is attached emerged hydrophyte, the stomata are present on
  - (a) Adaxial (upper) surface of leaf
  - (b) Abaxial (lower) surface of leaf
  - (c) On both surface of leaf
  - (d) None of the above

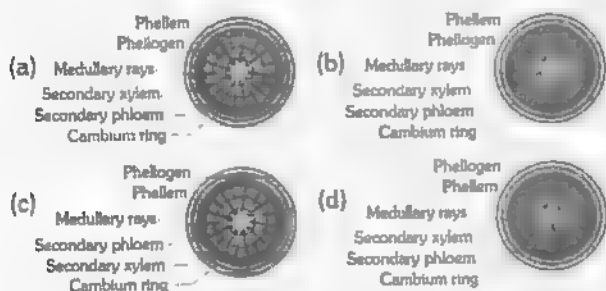
24. Multiple epidermis on dorsal and ventral side of the leaf is found in [CBSE PMT 1990; BHU 1994]  
(a) *Zea mays* (b) *Ficus benghalensis*  
(c) *Mangifera indica* (d) *Nerium oleander*
25. Amphiphloic (bicollateral) condition of stele means that [RPMT 1997; BVP 2003]  
(a) Phloem is surrounded by xylem  
(b) Phloem is on both sides of xylem  
(c) Phloem is internal to xylem  
(d) Phloem is external to xylem
26. When formation of metaxylem is in a centripetal manner, the xylem is [BHU 1994]  
(a) Endarch (b) Exarch  
(c) Mesarch (d) Radial
27. Druse is a crystal or deposit of  
(a) Calcium oxalate (b) Calcium carbonate  
(c) Starch (d) Silica
28. The most primitive type of stele is [CPMT 2001]  
(a) Eustele (b) Solenostele  
(c) Protostele (d) Siphonostele
29. Match the items in Column - I with Column - II and choose the correct option
- | Column - I |                              | Column - II |                       |
|------------|------------------------------|-------------|-----------------------|
| A.         | Radial Vascular Bundle       | 1.          | <i>Cucurbita pepo</i> |
| B.         | Collateral Vascular Bundle   | 2.          | <i>Dracaena</i>       |
| C.         | Bicollateral Vascular Bundle | 3.          | Roots of angiosperms  |
| D.         | Amphicribal Vascular Bundle  | 4.          | Sunflower stem        |
| E.         | Amphivasal Vascular Bundle   | 5.          | Fern                  |
- [Kerala PMT 2007]
- (a) A-3, B-4, C-1, D-5, E-2  
(b) A-2, B-3, C-1, D-5, E-4  
(c) A-3, B-4, C-5, D-1, E-2  
(d) A-4, B-5, C-1, D-2, E-3  
(e) A-3, B-1, C-2, D-4, E-5
30. Passage cells are found in [AIIMS 2002]  
(a) Dicot stem (b) Aerial root  
(c) Monocot root (d) Monocot stem
31. Trabeculae is the transformation of [MP PMT 2003]  
(a) Pericycle (b) Endodermis  
(c) Xylem (d) Phloem
32. A bicollateral vascular bundle has the following arrangement of tissues [KCET 2004]  
(a) Outer phloem - outer xylem - middle cambium - inner xylem - inner phloem  
(b) Outer cambium - Outer phloem - middle xylem - inner phloem - inner cambium  
(c) Outer phloem - outer cambium - middle xylem - inner cambium - inner phloem  
(d) Outer xylem - outer cambium - middle phloem - inner cambium - inner xylem
33. Amphivasal vascular bundle possess [RPMT 2006]  
(a) Xylem around phloem  
(b) Phloem around xylem  
(c) Phloem on both sides of xylem  
(d) Phloem towards centre and xylem towards periphery
34. A dicot plant in which scattered vascular bundles are present in stem is [AFMC 2012]  
(a) *Yucca* (b) *Peperomia*  
(c) *Dolichos* (d) *Helianthus*
35. Vascular tissue is well developed in [MHCET 2001]  
(a) Hydrophytes (b) Mesophytes  
(c) Xerophytes (d) None of these
36. Vascular bundle in monocotyledons are considered closed, when [Odisha JEE 2004; AFMC 2010; CBSE PMT (Pre.) 2012; AIPMT (Cancelled) 2015]  
(a) Cambium present (b) Cambium absent  
(c) Pericycle absent (d) None of these
37. In the leaf vascular bundles are found in the [Kerala CET 2003]  
(a) Veins (b) Palisade tissue  
(c) Lower epidermis (d) Upper epidermis
38. Protosteles are found in [MP PMT 2002]  
(a) Bryophyta (b) Gymnosperms  
(c) Pteridophyta (d) Angiosperms
39. Which of the following have sunken stomata [RPMT 2002]  
(a) *Nerium* (b) *Mangifera*  
(c) *Hydrilla* (d) *Zea mays*
40. Some vascular bundles are described as open because these [NCERT; CBSE PMT (Maine) 2011]  
(a) Possess conjunctive tissue between xylem and phloem  
(b) Are not surrounded by pericycle  
(c) Are surrounded by pericycle but no endodermis  
(d) Are capable of producing secondary xylem and phloem
41. Vascular cambium in dicot root develops from [DPMT 2004]  
Or  
In dicot root, initiation of lateral root and vascular cambium during secondary growth takes place from [NCERT]  
(a) Endodermis (b) Pericycle  
(c) Conjunctive parenchyma (d) Both (b) and (c)
42. The large, empty and colourless cells present at intervals on the upper surface of grass leaf are called [Kerala PMT 2006, 11]  
(a) Bulliform cells (b) Palisade parenchyma  
(c) Spongy parenchyma (d) Accessory cells  
(e) Passage cells
43. Amphicribal or hadrocentric vascular bundles are present in the stem of  
(a) *Selaginella* (b) *Dracaena*  
(c) *Cucurbita* (d) *Zea mays*
44. In free floating plant, the stomata are [AFMC 2000]  
(a) Absent  
(b) Present on upper surface  
(c) Present on both the surface  
(d) Present on lower surface

45. Pith cells are found in [RPMT 1995]  
(a) Epidermis (b) Endodermis  
(c) Pericycle (d) Lenticels
46. Dorsiventral leaf has [Kerala CET 2002]  
(a) Stomata on both side (b) Stomata on lower surface  
(c) Stomata on upper surface (d) No stomata
47. Root hairs are found [NCERT; Kerala CET 2003; NEET 2017]  
(a) In the zone of maturation (b) Adventitious roots  
(c) On the root cap (d) Apical meristem
48. Raphides are needle-like crystals of calcium oxalate which are specially found in [Bihar MDAT 1995; MP PMT 1996; CPMT 2000; Odisha JEE 2004]  
(a) Pistia (b) Rose  
(c) Asparagus (d) Dahlia
49. Which of the following do not have stomata [AIIMS 2000]  
(a) Xerophytes (b) Mesophytes  
(c) Hydrophytes (d) Submerged hydrophytes
50. Passage cells are present in [KCET 2000]  
(a) Epidermis (b) Endodermis  
(c) Xylem (d) Lenticels and hydathodes
51. When xylem and phloem are separated by a strip of cambium it is called [KCET 1998]  
(a) Collateral and open (b) Collateral and closed  
(c) Bicollateral and open (d) Concentric and closed
52. Cortex is the region found between [NEET (Phase-II) 2016]  
(a) Endodermis and vascular bundle  
(b) Epidermis and stele  
(c) Pericycle and endodermis  
(d) Endodermis and pith

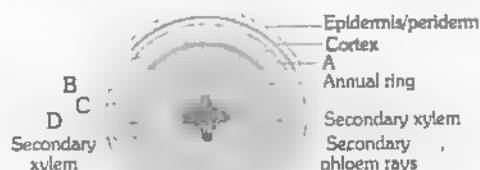
### Internal structure of root, stem and leaf

1. Exarch and polyarch vascular bundles occur in [MP PMT 2000, 06]  
(a) Monocot stem (b) Monocot root  
(c) Dicot stem (d) Dicot root
2. Bicollateral conjoint vascular bundles have [Kerala PMT 2006]  
(a) Xylem and phloem, which are arranged in an alternate manner on different radii  
(b) Xylem and phloem, which are situated at the same radius and it has two groups of phloem along the two sides of xylem (inside and outside)  
(c) Xylem and phloem in same radius but it has only one group phloem outside the xylem  
(d) Phloem surrounds the xylem tissues  
(e) Xylem surrounds the phloem tissues
3. Velamen tissue in orchids is found in [RPMT 2002]  
(a) Shoot (b) Root  
(c) Leaves (d) Flowers
4. Casparian thickenings are found in the cells of [CPMT 1999; KCET 2006; Odisha JEE 2011]  
Or  
In dicot roots, cells of which region show casparian strips [RPMT 1997; CBSE PMT 1999; Odisha JEE 2005]  
(a) Pericycle of the root (b) Endodermis of the root  
(c) Pericycle of the stem (d) Endodermis of the stem
5. In monocot leaf [CBSE PMT 1990]  
(a) Bulliform cells are absent from the epidermis  
(b) Veins form a network  
(c) Mesophyll is well differentiated into these parts  
(d) Mesophyll is not differentiated into palisade and spongy parenchyma
6. Find out the wrong statement about angiosperm roots [KCET 2012]  
(a) Cuticle is absent in young stages  
(b) The apex is protected by root cap  
(c) Vascular bundles are collateral  
(d) Xylem is centripetal in growth in the young roots
7. A major characteristic of the monocot root is the presence of [AIPMT (Cancelled) 2015]  
(a) Scattered vascular bundles  
(b) Vasculture without cambium  
(c) Cambium sandwiched between phloem and xylem along the radius  
(d) Open vascular bundles
8. The correct situation of mesophyll in isobilateral grass leaf is shown by  
(a) Palisade towards adaxial surface  
(b) Palisade towards abaxial surface  
(c) Undifferentiated mesophyll  
(d) Palisade along both the surface
9. Leaf mesophylls are composed of [Odisha JEE 2008]  
(a) Palisade parenchyma (b) Spongy parenchyma  
(c) Both of them (d) None of these
10. Vascular bundles are scattered in [Kerala CET 2002; CPMT 1990]  
(a) Bryophytes (b) Dicot root  
(c) Dicot stem (d) Monocot stem
11. Generally hypodermis in monocots is composed of  
(a) Parenchyma (b) Sclerenchyma  
(c) Collenchyma (d) Chlorenchyma
12. Kranz anatomy is found in [CPMT 1998]  
(a) Monocots (b) Dicots  
(c) Both (a) and (b) (d) None of these
13. Which of the following is not a characteristic feature of the anatomy of dicotyledonous root  
(a) Radial vascular bundles  
(b) Secondary growth  
(c) Pith little or absent  
(d) Vascular bundles 15 – 20
14. Origin of lateral root of secondary root is  
(a) Exogenous (b) Endogenous  
(c) Lysigenous (d) Schizogenous
15. In a vertical section of a dorsiventral leaf, the protoxylem in its midrib bundle [BHU 1994]  
(a) Faces the dorsal epidermis of the leaf  
(b) Faces the ventral epidermis of the leaf  
(c) Is not distinct  
(d) Is surrounded by metaxylem

16. The annular and spirally thickened conducting elements generally develop in the protoxylem when the root or stem is [CBSE PMT 2009]  
 (a) Maturing (b) Elongating  
 (c) Widening (d) Differentiating
17. In barley stem vascular bundles are [CBSE PMT 2009]  
 (a) Open and scattered  
 (b) Closed and scattered  
 (c) Open and in a ring  
 (d) Closed and radial
18. Anatomically fairly old dicotyledonous root is distinguished from the dicotyledonous stem by [CBSE PMT 2009, 14; Odisha JEE 2011]  
 (a) Absence of secondary xylem  
 (b) Absence of secondary phloem  
 (c) Presence of cortex  
 (d) Position of protoxylem
19. Palisade parenchyma is absent in leaves of [CBSE PMT 2009]  
 (a) Sorghum (b) Mustard  
 (c) Soybean (d) Gram
20. Exarch xylem is found in [CBSE PMT 1990; KCET 1999]  
 (a) Root (b) Stem  
 (c) Leaf (d) Rachis
21. The vascular cambial ring of a dicot stem is  
 (a) Primary in origin (b) Secondary in origin  
 (c) Embryonic in origin (d) Tertiary in origin  
 (e) Partly primary and partly secondary in origin
22. Consider the following statements  
 (A) In a dicot root, the vascular bundles are collateral and endarch  
 (B) The inner most layer of cortex in a dicot root is endodermis  
 (C) In a dicot root, the phloem masses are separated from the xylem by parenchymatous cells that are known as the conjunctive tissue  
 Of these statements given above [Kerala PMT 2008]  
 (a) A is true, but B and C are false  
 (b) B is true, but A and C are false  
 (c) A is false, but B and C are true  
 (d) C is false, but A and C are true  
 (e) C is true, but A and B are false
23. Which of the following figure of dicot stem is correctly labelled [NCERT]

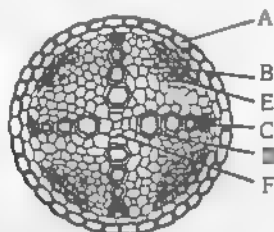


24. The following figure is old typical dicot root. Identify A, B, C and D [NCERT]



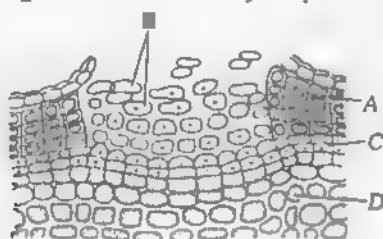
- (a) A – Secondary phloem, B – Primary xylem, C – Primary phloem, D – Vascular cambium  
 (b) A – Primary phloem, B – Primary xylem, C – Secondary phloem, D – Vascular cambium  
 (c) A – Secondary phloem, B – Vascular cambium, C – Primary phloem, D – Primary xylem  
 (d) A – Primary phloem, B – Vascular cambium, C – Secondary phloem, D – Primary xylem
25. Vascular bundles in dicot stem are [MHCET 2001; Odisha JEE 2012; PET (Pharmacy) 2013]  
 (a) Conjoint and collateral  
 (b) Conjoint and closed  
 (c) Conjoint, collateral and open  
 (d) Collateral and open
26. Which of the following is correct sequence of layers in typical monocot root (from outer surface to inside) [CPMT 2005]  
 (a) Pericycle, cortex, endodermis, epiblema  
 (b) Epiblema, endodermis, cortex, pericycle  
 (c) Epiblema, cortex, endodermis, pericycle  
 (d) Epiblema, pericycle, cortex, endodermis
27. Monocot root differs from dicot root in [NCERT; AMU (Med.) 2005; CBSE PMT (Main) 2012]  
 (a) Presence of more than six xylem bundle  
 (b) Well developed pith  
 (c) Absence of secondary growth  
 (d) All of these
28. Pith is a central part of the ground tissue generally made up of [J & K CET 2005]  
 (a) Parenchyma (b) Collenchyma  
 (c) Chlorenchyma (d) Sclerenchyma
29. In a dorsiventral leaf, location of palisade tissue and phloem respectively are [NCERT; RPMT 1999]  
 (a) Abaxial and abaxial (b) Adaxial and abaxial  
 (c) Adaxial and adaxial (d) Abaxial and adaxial
30. T.S. of stem of *Cucurbita* can be identified from the T.S. of sunflower stem by the presence of  
 (a) Bicollateral vascular bundles  
 (b) Conjoint vascular bundles  
 (c) Scattered vascular bundles  
 (d) Cambium in the vascular bundles
31. Which of the following is seen in a monocot root  
 (a) Large pith (b) Vascular cambium  
 (c) Endarch xylem (d) Medullary ray
32. In monocot stem, following is absent [DPMT 2004]  
 (a) Endodermis (b) Hypodermis  
 (c) Cortex (d) Both (a) and (b)

33. In the diagram of T.S. of Stele of Dicot Root, the different parts have been indicated by alphabets; choose the answer in which these alphabets correctly match with the parts they indicate [KCET 2004]



- (a) A = Endodermis  
B = Conjunctive tissue  
C = Metaxylem  
D = Protoxylem  
E = Phloem  
F = Pith
- (b) A = Endodermis  
B = Pith  
C = Protoxylem  
D = Metaxylem  
E = Protoxylem  
F = Conjunctive tissue
- (c) A = Pericycle  
B = Conjunctive tissue  
C = Metaxylem  
D = Protoxylem  
E = Phloem
- (d) A = Endodermis  
B = Conjunctive tissue  
C = Protoxylem  
D = Metaxylem  
E = Phloem  
F = Pith

34. In the diagram of lenticel identify the parts as A, B, C, D



[KCET 2007]

- (a) A - phellem, B - periderm, C - phellogen, D - phelloderm
- (b) A - phellem, B - complementary cells, C - phelloderm, D - periderm
- (c) A - complementary cells, B - phellogen, C - phelloderm, D - periderm
- (d) A - complementary cells, B - phellem, C - periderm, D - phelloderm

35. Centripetal xylem is the characteristic of
- (a) Roots (b) Stems  
(c) Leaf (d) Petiole

36. In monocot roots which types of vascular bundles are found [BHU 2003]

- (a) Collateral, conjoint and closed  
(b) Radial V.B. with exarch xylem  
(c) Bicolateral, conjoint and closed  
(d) Radial V.B. with endarch xylem

37. Conjoint, collateral and closed vascular bundle is found in [RPMT 1995, 2002; CPMT 1998; BHU 2002; BCECE 2005; AMU (Med.) 2009]

- (a) Monocot stem (b) Monocot root  
(c) Dicot stem (d) Dicot root

38. Collenchyma tissue is present in [RPMT 1995]  
Or

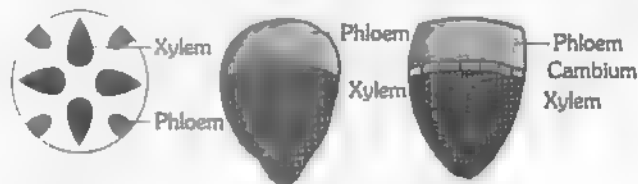
Collenchymatous hypodermis is characteristics of

- (a) Dicot stem (b) Monocot stem  
(c) Dicot root (d) Flowers

39. Largest number of chloroplast is found in [CPMT 2004]

- (a) Pallsade tissue (b) Spongy tissue  
(c) Transfusion tissue (d) Bundle sheath cells

40. Which type of vascular bundles are found in A, B and C [NCERT]



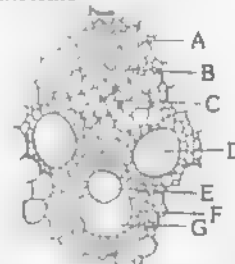
- (a) Bicolateral; Concentric; Radial  
(b) Open collateral conjoint; Close collateral conjoint; Radial  
(c) Close collateral conjoint; Open collateral conjoint; Radial  
(d) Radial; Close collateral conjoint; Open collateral conjoint

41. The following types of vascular bundles (A, B and C) are present in [NCERT]



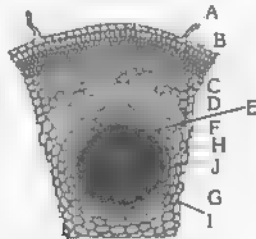
- (a) Monocot stem and leaf, dicot root, monocot leaf respectively  
(b) Root, monocot stem and leaf, dicot stem respectively  
(c) Root, stem, leaf respectively  
(d) Stem, root, leaf respectively

42. The following diagrams shows the cross-section of the vascular bundle of monocot stem given aside, different parts have been indicated by alphabets; choose the option in which these alphabets have been correctly matched with the parts which they indicate [NCERT]

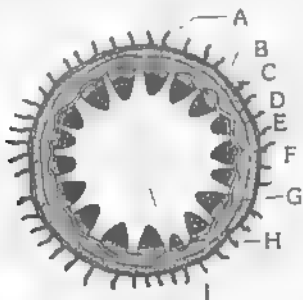


- (a) A = Bundle cap, B = Metaxylem, C = Metaphloem, D = Protoxylem, E = Protophloem, F = Lysigenous cavity, G = Xylem parenchyma
- (b) A = Bundle sheath, B = Primary phloem, C = Secondary phloem, D = Primary xylem, E = Secondary xylem, F = Xylem fibres, G = Hydathode
- (c) A = Bundle cap, B = Metaphloem, C = Protophloem, D = Protoxylem, E = Metaxylem, F = Lysigenous cavity, G = Xylem parenchyma
- (d) A = Bundle sheath, B = Broken phloem, C = Metaphloem, D = Metaxylem, E = Protoxylem, F = Xylem parenchyma, G = Lysigenous cavity

43. The following diagram illustrates the TS of monocot root in which certain parts have been indicated by alphabets, choose the right answer in which these alphabets have been correctly matched with the parts which they indicate [NCERT]

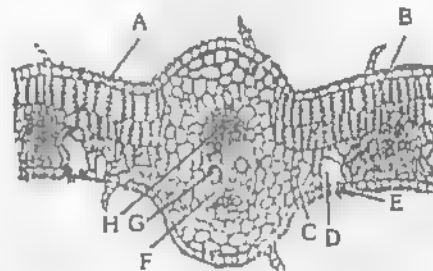


- (a) A = Root hair, B = Cortex, C = Epiblema, D = Pericycle, E = Endodermis, F = Pith, G = Passage cell, H = Phloem, I = Protoxylem, J = Metaxylem  
 (b) A = Root hair, B = Epiblema, C = Cortex, D = Endodermis, E = Pericycle, F = Passage cell, G = Phloem, H = Pith, I = Protoxylem, J = Metaxylem  
 (c) A = Root hair, B = Epiblema, C = Cortex, D = Endodermis, E = Passage cell, F = Pith, G = Pericycle, H = Metaxylem, I = Phloem, J = Protoxylem  
 (d) A = Root hair, B = Epiblema, C = Cortex, D = Endodermis, E = Passage cell, F = Pericycle, G = Pith, H = Phloem, I = Metaxylem, J = Protoxylem
44. The following diagram shows the TS of dicot stem, certain parts have been indicated by A, B, C, D, E, F, G, H and I. Select the right answer in which these alphabets have been correctly matched with the parts which they indicate [NCERT]

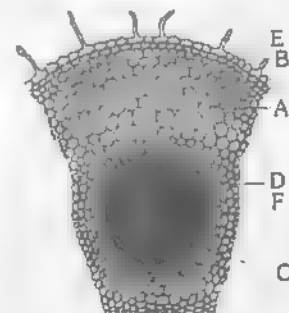


- (a) A = Epidermal hairs, B = Epidermis, C = Parenchyma, D = Hypodermis (Collenchyma), E = Starch sheath, F = Vascular bundle, G = Bundle cap, H = Medulla or pith, I = Medullary rays  
 (b) A = Epidermal hairs, B = Epidermis, C = Hypodermis (Collenchyma), D = Starch sheath, E = Parenchyma, F = Vascular bundle, G = Bundle cap, H = Medulla or pith, I = Medullary rays  
 (c) A = Epidermal hairs, B = Epidermis, C = Hypodermis (Collenchyma), D = Parenchyma, E = Starch sheath, F = Bundle cap, G = Vascular bundle, H = Medullary rays, I = Medulla or pith  
 (d) A = Epidermis, B = Epidermal hairs, C = Parenchyma, D = Starch sheath, E = Hypodermis (Collenchyma), F = Vascular bundle, G = Bundle cap, H = Medulla or pith, I = Medullary rays

45. The following diagram shows the TS of dicot leaf passing through the midrib, some parts have been indicated by alphabets. Choose the answer in which A, B, C, D, E, F, G and H have been correctly matched with the parts which they indicate [NCERT]

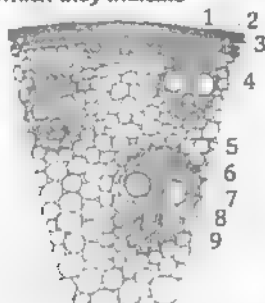


- (a) A = Epidermis, B = Palisade parenchyma, C = Spongy parenchyma, D = Stomata, E = Guard Cells, F = Phloem, G = Metaxylem, H = Protoxylem  
 (b) A = Epidermis, B = Palisade parenchyma, C = Spongy parenchyma, D = Stomata, E = Guard cells, F = Endodermis, G = Xylem, H = Phloem  
 (c) A = Epidermis, B = Palisade parenchyma, C = Spongy Parenchyma, D = Sub stomatal cavity, E = Guard cells, F = Phloem, G = Metaxylem, H = Protoxylem  
 (d) A = Epidermis, B = Spongy parenchyma, C = Palisade parenchyma, D = Stomata, E = Guard cells, F = Phloem, G = Metaxylem, H = Protoxylem
46. The following diagram shows the TS of dicot root, certain parts have been indicated by letters, select the option in which these letters have been correctly matched with the parts which they indicate [NCERT]



- (a) A = Cortex, B = Epiblema, C = Pith, D = Endodermis, E = Root hair, F = Pericycle  
 (b) A = Epiblema, B = Endodermis, C = Cortex, D = Root hair, E = Pith, F = Pericycle  
 (c) A = Cortex, B = Pith, C = Epiblema, D = Endodermis, E = Root hair, F = Pericycle  
 (d) A = Epiblema, B = Root hair, C = Cortex, D = Endodermis, E = Pith, F = pericycle

47. The given below diagram shows the T.S. of monocot stem, some parts have been indicated by numbers. Select the answer in which these numbers have been correctly matched with the parts which they indicate [NCERT]



- (a) 1 - Cuticle, 2 - Epidermis, 3 - Sclerenchymatous hypodermis, 4 - Sclerenchymatous sheath, 5 - Parenchymatous sheath, 6 - Protoxylem, 7 - Metaxylem, 8 - Phloem, 9 - Water cavity  
 (b) 1 - Cuticle, 2 - Epidermis, 3 - Sclerenchymatous hypodermis, 4 - Sclerenchymatous sheath, 5 - Parenchymatous sheath, 6 - Phloem, 7 - Protoxylem, 8 - Metaxylem, 9 - Water cavity  
 (c) 1 - Cuticle, 2 - Epidermis, 3 - Sclerenchymatous sheath, 4 - Sclerenchymatous hypodermis, 5 - Parenchymatous sheath, 6 - Phloem, 7 - Metaxylem, 8 - Protoxylem, 9 - Water cavity  
 (d) 1 - Cuticle, 2 - Epidermis, 3 - Sclerenchymatous hypodermis, 4 - Sclerenchymatous sheath, 5 - Parenchymatous sheath, 6 - Phloem, 7 - Metaxylem, 8 - Protoxylem, 9 - Water cavity

### Secondary growth

1. In dicot stem, the secondary growth takes place by  
 (a) Primary cambium  
 (b) Secondary cambium  
 (c) Development of cambium in stele region  
 (d) Development of cambium in stele and in the cortical region
2. Which one of the following is not correct [AMU (Med.) 2010]  
 (a) Early wood is characterized by large number of xylary elements  
 (b) Early wood is characterized by vessels with wider cavities  
 (c) Late wood is characterized by large number of xylary elements  
 (d) Late wood is characterized by vessels with narrower cavities
3. Conduction of sap in plants occurs through  
 (a) Heartwood (b) Sapwood  
 (c) Xylem (d) All the above
4. "Sap wood" is otherwise called [J & K CET 2008; Kerala PMT 2009]  
 (a) Duramen (b) Alburnum  
 (c) Pith (d) Medullary rays
5. The function of cork cambium (phellogen) is to produce [Odisha JEE 2010]  
 (a) Cork and secondary cortex  
 (b) Secondary xylem and secondary phloem  
 (c) Cork  
 (d) Secondary cortex and phloem
6. Vascular tissues in flowering plants develop from [KCET 1998; CBSE PMT 2008]  
 (a) Periblem (b) Dermatogen  
 (c) Phellogen (d) Plerome
7. In dicot roots, cork cambium is derived from  
 (a) Epidermis (b) Hypodermis  
 (c) Cortex (d) Pericycle
8. Periderm is made up of [MP PMT 1995, 2010]  
 (a) Phellem (b) Phellogen  
 (c) Phelloderm (d) All the above
9. If four radial vascular bundles are present, then the structure will be [CBSE PMT 2002]  
 (a) Monocot stem (b) Monocot root  
 (c) Dicot stem (d) Dicot root
10. Secondary growth is absent in  
 (a) Dicot stem (b) Gymnosperms  
 (c) Monocot stem (d) Dicot root
11. Complementary cells are found in [Odisha JEE 2012]  
 (a) Pericycle (b) Endodermis  
 (c) Lenticels (d) Pith
12. Fascicular cambium found in dicot stem is a  
 (a) Secondary meristem (b) Primary meristem  
 (c) Intercalary meristem (d) Apical meristem
13. Which of the following meristems is responsible for extrastelar secondary growth in dicotyledonous stem [CBSE PMT 1998]  
 (a) Phellogen (b) Intrafascicular cambium  
 (c) Interfascicular cambium (d) Intercalary meristem
14. Heartwood differs from sapwood in [CBSE PMT (Pre.) 2010]  
 (a) Being susceptible to pests and pathogens  
 (b) Presence of rays and fibres  
 (c) Absence of vessels and parenchyma  
 (d) Having dead and non-conducting elements
15. Youngest layer of secondary xylem in wood of dicot stem is located just [CPMT 1993]  
 (a) Outside the cambium (b) Inside the cambium  
 (c) Outside pith (d) Inside the cortex
16. Annual rings are distinct in plants growing in  
 (a) Tropical regions (b) Arctic region  
 (c) Grasslands (d) Temperate region
17. Read the different components from (A) to (D) in the list given below and tell the correct order of the components with reference to their arrangement from outer side to inner side in a woody dicot stem [AIPMT 2015]  
 (A) Secondary cortex (B) Wood  
 (C) Secondary phloem (D) Phellem  
 (a) (A), (B), (D), (C) (b) (D), (A), (C), (B)  
 (c) (D), (C), (A), (B) (d) (C), (D), (B), (A)
18. Growth rings are well marked in trees growing in  
 (a) Shimla (b) Bombay  
 (c) Madras (d) Calcutta
19. As secondary growth proceeds, in a dicot stem, the thickness of [KCET 2006]  
 (a) Sapwood increases  
 (b) Heartwood increases  
 (c) Both sapwood and heartwood increases  
 (d) Both sapwood and heartwood remains the same

20. External protective tissues of plants are (of dicot stem are)  
 (a) Cork and pericycle (b) Cortex and epidermis  
 (c) Pericycle and cortex (d) Epidermis and cork
21. Cork cambium is a [MHCET 2000]  
 (a) Secondary meristem (b) Apical meristem  
 (c) Intercalary meristem (d) Primary meristem
22. The cambium which produces cork is known as  
 [EAMCET 1993; RPMT 1997; CPMT 1999; HPMT 2005]

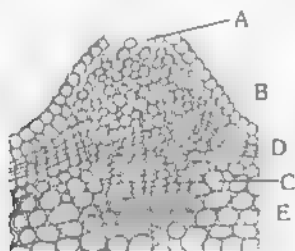
Or

The common bottle cork is a product of  
 [NCERT; CBSE PMT (Pre.) 2012]

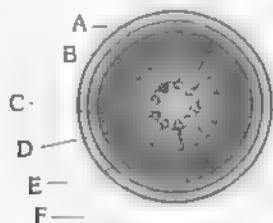
Or

The meristem that is parallel to the longitudinal axis of the plant is

- (a) Phelloderm (b) Phellogen  
 (c) Periblem (d) Periderm
23. The cork cambium, cork and secondary cortex are collectively called [NCERT; Kashmir MEE 1995; CBSE PMT (Pre.) 2011]  
 (a) Phellem (b) Phelloderm  
 (c) Phellogen (d) Periderm
24. Identify the correct combination of labelling a lenticel [NCERT]



- (a) A - pore, B - complimentary cells, C - cork, D - cork cambium, E - secondary cortex  
 (b) A - pore, B - cork, C - complimentary cells, D - cork cambium, E - secondary cortex  
 (c) A - pore, B - cork cambium, C - secondary cortex, D - cork, E - complimentary cells  
 (d) A - pore, B - secondary cortex, C - cork cambium, D - cork, E - complimentary cells
25. The following figure showing secondary growth in dicot stem. Identify A, B, C, D, E and F [NCERT]



- (a) A - Phellem, B - Phellogen, C - Cambium ring, D - Secondary xylem, E - Secondary phloem, F - Medullary rays  
 (b) A - Phellogen, B - Phellem, C - Medullary rays, D - Secondary xylem, E - Secondary phloem, F - Cambium ring  
 (c) A - Phellem, B - Phellogen, C - Medullary rays, D - Secondary phloem, E - Secondary xylem, F - Cambium ring  
 (d) A - Phellem, B - Phellogen, C - Medullary rays, D - Secondary xylem, E - Secondary phloem, F - Cambium ring

26. In dicot stem secondary growth is due to the activity of [Pb. PMT 2004, 05]  
 (a) Apical meristem (b) Lateral meristem  
 (c) Cork (d) Back
27. The cell wall is impermeable to water and deposition of suberin is also found in [CPMT 1998]  
 (a) Bast (b) Cork  
 (c) Bark (d) Xylem
28. Secondary growth is absent in [CPMT 1998]  
 (a) Hydrophytes (b) Mesophytes  
 (c) Halophytes (d) Xerophytes
29. Girth of a dicot stem is increased by [Pune CET 1998]  
 (a) Xylem (b) Cambium  
 (c) Phloem (d) Ground tissue
30. Tyloses are found in [MP PMT 1996; KCET 2010; Odisha JEE 2012]  
 (a) Secondary xylem (b) Secondary phloem  
 (c) Callus tissue (d) Cork cells
31. Fusiform initials form [MP PMT 2007]  
 (a) Vascular rays (b) Treacheary elements  
 (c) Ray parenchyma (d) Phloem parenchyma
32. In the primary tissues of the stem, the cambium separating xylem and phloem is called  
 (a) Procambium (b) Fascicular cambium  
 (c) Cork cambium (d) Interfascicular cambium
33. The trees growing in desert will  
 (a) Show alternate rings of xylem and sclerenchyma  
 (b) Have only conjunctive tissue and phloem formed by the activity of cambium  
 (c) Show distinct annual rings  
 (d) Not show distinct annual rings
34. The bark of tree comprises [NCERT; CPMT 1996; Pune CET 1998]  
 (a) All the tissues outside the vascular cambium  
 (b) All the tissues outside the cork cambium  
 (c) Only the cork  
 (d) The cork and secondary cortex
35. Knots in stems are formed due to  
 (a) Tumors formed due to bacterial infection of wounds  
 (b) Outgrowth of secondary tissue over wounds  
 (c) Injury caused by insects  
 (d) None of the above
36. The vascular cambium in dicots is [EAMCET 1995]  
 (a) Lateral (b) Apical  
 (c) Intercalary (d) Secondary
37. Secondary cortex is also known as [KCET 2012]  
 (a) Phellem (b) Phelloderm  
 (c) Phellogen (d) Bark
38. Annual growth rings are formed due to activity [CPMT 2004; MP PMT 2006]  
 (a) Extrastelar cambium (b) Intrastelar cambium  
 (c) Interstelar cambium (d) Both (b) and (c)
39. As a tree grows older, which increases rapidly in thickness  
 (a) Its heart wood (b) Its cortex  
 (c) Its sap wood (d) Its phloem



40. The axillary buds arise [MP PMT 2013]  
(a) Endogenously from the pericycle  
(b) Exogenously from the tissues of the main growing point  
(c) Endogenously from the cambial tissues  
(d) Exogenously from the innermost cortex
41. Lenticel develops through the activity of  
(a) Vascular cambium (b) Dermatogen  
(c) Phellogen (d) Intercalary meristem
42. In a stratified cambium, the fusiform initials are [CBSE PMT 1994]  
(a) Long and overlap each other at the ends  
(b) Short and overlap each other at the ends  
(c) Short and arranged in horizontal tiers  
(d) Short or long and overlap each other at the ends
43. Intrafascicular cambium is situated in [BVP 2003]  
(a) Outside the vascular bundles  
(b) In medullary rays  
(c) Inside the vascular bundles  
(d) In between the vascular bundles
44. Lenticels are [NCERT; Odisha JEE 2009]  
(a) Loose cells on leaves  
(b) Subsidiary cells of stomata  
(c) Cells for respiration in epiphytes  
(d) Some loose cells on bark meant for aeration
45. In an annual ring, the light coloured part is known as [DUMET 2009]  
(a) Early wood (b) Late wood  
(c) Heartwood (d) Sapwood
46. In old dicot stems, a major part of the wood is filled up with tannins, resins, gums etc. This part of wood is called  
(a) Hard wood (b) Heart wood  
(c) Sap wood (d) Soft wood
47. In summer, cambium  
(a) Dies (b) Is more active  
(c) Is less active (d) Is not active
48. What is/are true about heart wood  
A. It does not help in water conduction  
B. It is also called alburnum  
C. It is dark in colour but very soft  
D. It has tracheary element which are filled with tannin, resin, etc. [NCERT; KCET 2009]  
(a) B, C and D (b) A and D  
(c) B and D (d) A, B and C
49. Identify the correct statement [KCET 2009]  
(a) Because of marked climatic variations, plants growing near the sea shore do not produce annual rings  
(b) The age of the plant can be determined by its height  
(c) Healing of damaged tissue is because of the activity of sclerenchyma cells  
(d) Grafting is difficult in monocot plants as they have scattered vascular bundles
50. For a critical study of secondary growth in plants, which one of the following pairs is suitable [CBSE PMT 2007]  
(a) Sugarcane and sunflower  
(b) Teak and pine  
(c) Deodar and fern  
(d) Wheat and maiden hair fern
51. Vascular cambium is a meristematic layer that cuts off [CBSE PMT 1990]  
(a) Primary xylem and primary phloem  
(b) Xylem vessels and xylem tracheids  
(c) Primary xylem and secondary xylem  
(d) Secondary xylem and secondary phloem
52. The waxy substance associated with cell walls of cork cells is or cork cells are impervious to water because of the presence of what is deposited on cork cells [NCERT; AIIMS 1992, 2004; CBSE PMT 1994; MP PMT 2000]  
(a) Cutin (b) Suberin  
(c) Lignin (d) Hemicellulose
53. Which of the following statements is / are not true  
A. Cork cambium is otherwise called phellogen  
B. Cork is otherwise called phellem  
C. Secondary cortex is otherwise called periderm  
D. Cork cambium, cork and secondary cortex are collectively called phelloderm [Kerala PMT 2006, 07]  
(a) C and D only (b) A and B only  
(c) B and C only (d) B and D only  
(e) A and D only
54. The functional xylem of dicot tree is [AFMC 2001]  
(a) Sap wood (b) Hard wood  
(c) Heart wood (d) Autumn wood
55. Which will decay faster if exposed freely [CBSE PMT 1993]  
(a) Soft wood (b) Heart wood  
(c) Sap wood (d) Wood with lots of fibres
56. In dicot stem, vascular bundles are [NCERT; Odisha JEE 2004]  
(a) Numerous scattered  
(b) Arranged in a ring  
(c) Without cambium  
(d) Surrounded by bundle sheath
57. The best method to determine the age of tree is [MP PMT 2004; NEET 2013]  
(a) To find out the number of branches  
(b) To count the number of annual rings  
(c) To measure its diameter  
(d) To count the number of leaves
58. Removal of ring wood of tissue outside the vascular cambium from the tree trunk kills it because [RPMT 2005]  
(a) Water cannot move up  
(b) Food does not travel down and root become starved  
(c) Shoot become starved  
(d) Annual ring and not produced

59. After the secondary growth the youngest layer of secondary phloem in a dicot stem is located  
(a) Just outside the vascular cambium  
(b) Just inside the vascular cambium  
(c) Just inside the primary phloem  
(d) Just outside the secondary xylem
60. Cork is a derivative of  
(a) Cork cambium (phellogen) or extra fascicular cambium  
(b) Vascular cambium  
(c) Fascicular cambium  
(d) Interfascicular cambium
61. Which of the following is known as wood [AFMC 2003]  
(a) Primary xylem (b) Secondary xylem  
(c) Secondary phloem (d) Cambium
62. Heart wood or duramen is [KCET 2001; BHU 2006]  
(a) Outer region of secondary xylem  
(b) Inner region of secondary xylem  
(c) Outer region of secondary phloem  
(d) Inner region of secondary phloem
63. One cannot age a tree by its rings if that tree is located in which of the following forests  
(a) Tropical deciduous (b) Tropical evergreen  
(c) Temperate deciduous (d) Temperate evergreen
64. Commercial cork is obtained from [BHU 2003; MP PMT 2012]  
(a) Mango (b) Oak (*Quercus suber*)  
(c) *Ficus religiosa* (d) *Pinus*
65. The pores present in the wall of plant's stem i.e., called [NCERT; CPMT 1994]  
Or  
In a plant organ which is covered by periderm and in which the stomata are absent, some gaseous exchange still takes place through [AIIMS 2004]  
(a) Lenticels (b) Bark  
(c) Dalipore (d) All the above
66. Lenticels are found in [RPMT 1995]  
(a) Young dicot stem (b) Old dicot stem  
(c) Monocot root (d) Young root
67. Secondary growth or increase in diameter is due to [NCERT]  
(a) Ground meristem (b) Procambium  
(c) Cork and phelloderm (d) Vascular cambium
68. In the following how the sap wood is converted into heart wood [RPMT 2006]  
(a) By degeneration of protoplast of living cells  
(b) Tylosis formation  
(c) By deposition of resins, oil, gums  
(d) All of the above
69. Identify the wrong statement in context of heartwood [NEET 2017]  
(a) Organic compounds are deposited in it  
(b) It is highly durable  
(c) It conducts water and minerals efficiently  
(d) It comprises dead elements with highly lignified walls
70. Which of the following is made up of dead cells [NEET 2017]  
(a) Xylem parenchyma (b) Collenchyma  
(c) Phellem (d) Phloem

# NCERT

## Exemplar Questions

1. A transverse section of stem is stained first with safranin and then with fast green following the usual schedule of double staining for the preparation of a permanent slide. What would be the colour of the stained xylem and phloem [NCERT]  
(a) Red and green (b) Green and red  
(c) Orange and yellow (d) Purple and orange
2. Match the following and choose the correct option from below  
A. Meristem I. Photosynthesis, storage  
B. Parenchyma II. Mechanical support  
C. Collenchyma III. Actively dividing cells  
D. Sclerenchyma IV. Stomata  
E. Epidermal tissue V. Sclereids [NCERT]  
Options:  
(a) A-I, B-III, C-V, D-II, E-IV  
(b) A-III, B-I, C-II, D-V, E-IV  
(c) A-II, B-IV, C-V, D-I, E-III  
(d) A-V, B-IV, C-III, D-II, E-I
3. Match the following and choose the correct option from below  
A. Cuticle i. Guard cells  
B. Bulliform cells ii. Single layer  
C. Stomata iii. Waxy layer  
D. Epidermis iv. Empty colourless cell [NCERT]  
Options  
(a) A-III, B-IV, C-I, D-II  
(b) A-I, B-II, C-III, D-IV  
(c) A-III, B-II, C-IV, D-I  
(d) A-III, B-II, C-I, D-IV
4. Identify the tissue system from among the following [NCERT]  
(a) Parenchyma (b) Xylem  
(c) Epidermis (d) Phloem
5. Cells of this tissue are living and show angular wall thickening. They also provide mechanical support. The tissue is [NCERT]  
(a) Xylem (b) Sclerenchyma  
(c) Collenchyma (d) Epidermis
6. Epiblema of roots is equivalent to [NCERT]  
(a) Pericycle (b) Endodermis  
(c) Epidermis (d) Stele
7. A conjoint and open vascular bundle will be observed in the transverse section of [NCERT]  
(a) Monocot root (b) Monocot stem  
(c) Dicot root (d) Dicot stem
8. Interfascicular cambium and cork cambium are formed due to [NCERT]  
(a) Cell division (b) Cell differentiation  
(c) Cell dedifferentiation (d) Redifferentiation
9. Phellogen and Phellem respectively denote [NCERT]  
(a) Cork and cork cambium  
(b) Cork cambium and cork  
(c) Secondary cortex and cork  
(d) Cork and secondary cortex

10. In which of the following pairs of parts of a flowering plant epidermis is absent [NCERT]
  - (a) Root tip and shoot tip
  - (b) Shoot bud and floral bud
  - (c) Ovule and seed
  - (d) Petiole and pedicel
11. How many shoot apical meristems are likely to be present in a twig of a plant possessing, 4 branches and 26 leaves [NCERT]
  - (a) 26
  - (b) 1
  - (c) 5
  - (d) 30
12. A piece of wood having no vessels (trachea) must be belong to [NCERT]
  - (a) Teak
  - (b) Mango
  - (c) Pine
  - (d) Palm
13. A plant tissue, when stained, showed the presence of hemicellulose and pectin in cell wall of its cells. The tissue represents [NCERT]
  - (a) Collenchyma
  - (b) Sclerenchyma
  - (c) Xylem
  - (d) Meristem
14. Fibres are likely to be absent in [NCERT]
  - (a) Secondary phloem
  - (b) Secondary Xylem
  - (c) Primary phloem
  - (d) Leaves
15. When we peel the skin of a potato tuber, we remove [NCERT]
  - (a) Periderm
  - (b) Epidermis
  - (c) Cuticle
  - (d) Sapwood
16. A vesselless piece of stem possessing prominent sieve tubes would belong to [NCERT]
  - (a) *Pinus*
  - (b) *Eucalyptus*
  - (c) Grass
  - (d) *Trochodendron*
17. Which one of the following cell types always divides by anticlinal cell division [NCERT]
  - (a) Fusiform initial cells
  - (b) Root cap
  - (c) Protoderm
  - (d) Phellogen
18. What is the fate of primary xylem in a dicot root showing extensive secondary growth [NCERT]
  - (a) It is retained in the centre of the axis
  - (b) It gets crushed
  - (c) May or may not get crushed
  - (d) It gets surrounded by primary phloem
2. In woody dicotyledons, the arrangement of vessels is either diffuse porous or ring porous. Based on these data, which one of the following statements is correct [BHU 1994]
  - (a) Ring porous vessels are specialised and are used for conducting more water for a shorter period only, when tyloses occur early in the vessels
  - (b) Although diffuse porous vessels are not so specialized as ring porous vessels, they conduct more water at all periods and through new xylem vessels added gradually during development
  - (c) Diffuse porous vessels carry more water and also faster because of a greater number of small vessels having greater capillary force
  - (d) Ring porous vessels conduct more water as they are formed early during development, when the need for water is great
3. The quiescent centre in root meristem serves as a [AIIMS 2003]
  - (a) Site for storage of food, which is utilized during maturation
  - (b) Reservoir of growth hormones
  - (c) Reserve for replenishment of damaged cells of the meristem
  - (d) Region for absorption of water
4. For a successful graft, the adhesion between stock and scion is a must. Which one of the following is the earliest event towards a good graft [CBSE PMT 1990]
  - (a) Production of plasmodesmata in the cells at the interface of stock and scion
  - (b) Coordinated differentiation of vascular tissue between the stock and scion
  - (c) Regeneration of cortex and epidermis over the union of stock and scion
  - (d) Production of callus tissue between the cells of stock and scion
5. If there is more than one tunica layer in a stem apex, which among the following is most likely to happen
  - (a) All the layers will develop into epidermal cells
  - (b) Only the outer layer will develop into epidermal cells
  - (c) All the layers will develop into cortex
  - (d) Inner layer develops into cortex
6. Water containing cavities in vascular bundles are found in [NCERT; CBSE PMT (Pre.) 2012]
  - (a) Sunflower
  - (b) Maize
  - (c) *Cycas*
  - (d) *Pinus*
7. A nail is driven into the trunk of a 30 year old tree at a point 1 meter above the soil level. The tree grows in height at the rate of 0.5 meters a year. After three years, the nail will be [Kerala PMT 2004]
  - (a) 1 meter above the soil
  - (b) 1.5 meter above the soil
  - (c) 2 meters above the soil
  - (d) 2.5 meters above the soil
  - (e) 3 meters above the soil level

## Critical Thinking

### Objective Questions

1. Match the following and choose the correct combination
 

(A) Endodermis	(1) Companion cells
(B) Stomata	(2) Lenticels
(C) Sieve tube	(3) Palisade cells
(D) Periderm	(4) Passage cells
(E) Mesophyll	(5) Accessory cells

 [Kerala PMT 2009]
  - (a) A-4, B-5, C-2, D-1, E-3
  - (b) A-5, B-3, C-1, D-2, E-4
  - (c) A-4, B-5, C-1, D-2, E-3
  - (d) A-2, B-5, C-3, D-4, E-1
  - (e) A-4, B-2, C-5, D-3, E-1

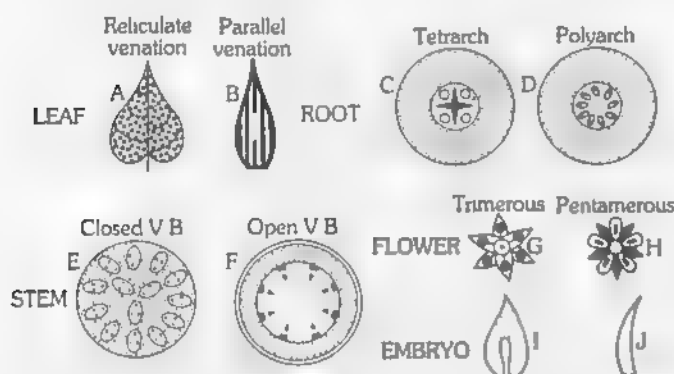
8. Grafting is not possible in monocots because they  
[BHU 1995; MP PMT 1996; AFMC 2010]

(a) Have scattered vascular bundles  
(b) Have parallel venation  
(c) Are herbaceous  
(d) Lack cambium

9. Trees at sea do not have annual rings because

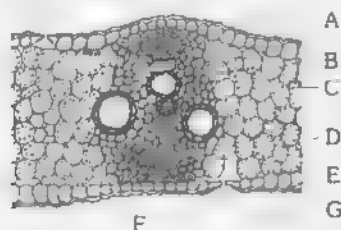
(a) Soil is sandy  
(b) There is climatic variation  
(c) There is no marked climatic variation  
(d) There is enough moisture in the atmosphere

10. See the following figures and identify the characters of Dicot and Monocot respectively  
[NCERT]



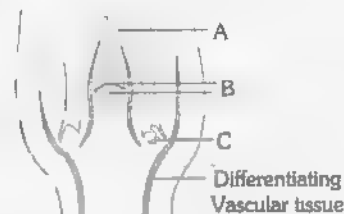
- (a) B, C, F, H, I; and A, D, E, G, J  
(b) A, C, E, G, I; and B, D, F, H, J  
(c) A, D, F, H, I; and B, C, E, G, J  
(d) A, C, F, H, I; and B, D, E, G, J

11. The following diagram shows the T.S. of monocot leaf, certain parts have been indicated by alphabets. Select the option in which A, B, C, D, E, F and G have been correctly matched with the parts which they indicate  
[NCERT]



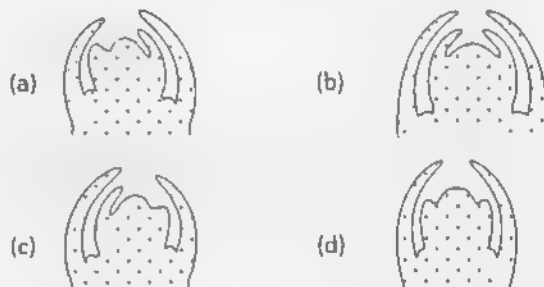
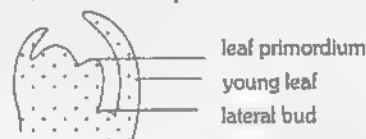
- (a) A – Adaxial epidermis, B – Xylem, C – Stoma, D – Sub-stomatal cavity, E – Abaxial epidermis, F – Phloem, G – Mesophyll  
(b) A – Adaxial epidermis, B – phloem, C – Mesophyll, D – Sub-stomatal cavity, E – Abaxial epidermis, F – Xylem, G – Stoma  
(c) A – Abaxial epidermis, B – Xylem, C – Mesophyll, D – Sub-stomatal cavity, E – Adaxial epidermis, F – Phloem, G – Stoma  
(d) A – Adaxial epidermis, B – Xylem, C – Mesophyll, D – Sub-stomatal cavity, E – Abaxial epidermis, F – Phloem, G – Stoma

12. Identify the following points A, B and C in the given diagram  
[NCERT]



- (a) A – Root hair primordium, B – Root apical meristem, C – Terminal bud  
(b) A – Root hair primordium, B – Root apical meristem, C – Axillary bud  
(c) A – Leaf primordium, B – Shoot apical meristem, C – Apical bud  
(d) A – Leaf primordium, B – Shoot apical meristem, C – Axillary bud

13. The following diagram opposite illustrates a longitudinal section through a shoot apex. Which of the figures given below shows the correct appearance of this shoot apex at the formation of the next leaf primordium  
[NCERT]



14. A few drops of sap were collected by cutting across a plant stem by a suitable method. The sap was tested chemically. Which one of the following test results indicated that it is phloem sap  
[NEET (Phase-II) 2016]

- (a) Absence of sugar (b) Acidic  
(c) Alkaline (d) Low refractive index

## Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

- (a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion  
(b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion  
(c) If the assertion is true but the reason is false  
(d) If both the assertion and reason are false  
(e) If the assertion is false but reason is true

1. Assertion : All tissues lying inside vascular cambium are called as bark.  
Reason : Bark is made up of phellogen, phellem and phelloderm lying inside secondary phloem.  
[AIIMS 1994]
2. Assertion : Stomata are absent in submerged hydrophytes.  
Reason : Respiration occurs by means of air chambers in submerged plants.  
[AIIMS 1997]
3. Assertion : Cambium is a lateral meristem and cause growth in width.  
Reason : Cambium is made up of fusiform and ray initials in stem.  
[AIIMS 1998]
4. Assertion : Higher plants have meristematic regions for indefinite growth  
Reason : Higher plants have root and shoot apices.  
[AIIMS 1999]
5. Assertion : In collateral vascular bundles phloem is situated towards inner side.  
Reason : In monocot stem, cambium is present  
[AIIMS 2000]
6. Assertion : Thick cuticle is mostly present in disease resistant plants.  
Reason : Disease causing agents cannot grow on cuticle and cannot invade the cuticle.  
[AIIMS 1997]
7. Assertion : Quiescent centre is found in the centre of the root apex.  
Reason : It consists of actively dividing cells.
8. Assertion : Sclerenchyma cells do not have plasmodesmata.  
Reason : The cell walls of some permanent tissues are heavily lignified.  
[KCET 2010]
9. Assertion : Intercalary meristem increase length of plant like apical meristems.  
Reason : Intercalary meristem originates from the apical meristems.
10. Assertion : Apical and intercalary meristems contribute to the growth in length, while the lateral meristems bring increase in girth in maize.  
Reason : Apical and intercalary meristems always increase the height of plants.  
[EAMCET 2009]
11. Assertion : Xerophytic leaves may contain stomatal crypts or sunken stomata.  
Reason : Spongy parenchyma is more in xerophytic leaves.
12. Assertion : Xylem and phloem are also called as leptome and hadrome respectively.  
Reason : Xylem and phloem form conducting tissue of the plant.
13. Assertion : The upper surface of the leaf is darker than the lower surface.  
Reason : Spongy mesophyll contains less chloroplasts than palisade mesophyll cells
14. Assertion : Tyloses plug the tracheids and vessels.  
Reason : Tyloses are in growths of xylem cells.
15. Assertion : Cuticle is also present in lower epidermal region of the leaf.  
Reason : The lower epidermis contains a large number of stomata.
16. Assertion : Bulliform cells are useful in the unrolling of leaf  
Reason : Bulliform leaves store water
17. Assertion : In grasses and cereals, intercalary meristems are not present.  
Reason : Intercalary meristems form permanent tissues
18. Assertion : Sapwood is less durable than the heartwood.  
Reason : Hollow tree trunks are due to the disappearance of sapwood
19. Assertion : Idioblasts are derived from parenchyma.  
Reason : Secretory cells are modified parenchyma.
20. Assertion : Growth rings are also called as annual rings.  
Reason : Generally growth ring is formed in each year.

## Answers

### Tissue (General)

1	c	2	a	3	a	4	a	5	c
6	a	7	d	8	d	9	e	10	b
11	d	12	b	13	d	14	d	15	b
16	b	17	b	18	e	19	e	20	b
21	a	22	b	23	c	24	d	25	b
26	a	27	b	28	d	29	b	30	b
31	a	32	c	33	a	34	d	35	a
36	d	37	b	38	a	39	c	40	b
41	d	42	d	43	c	44	b	45	c
46	a	47	b	48	c	49	a	50	d
51	d	52	a	53	a	54	d	55	c
56	b	57	c	58	b	59	d	60	a
61	d	62	a	63	a	64	a	65	b
66	d	67	a	68	a	69	b	70	b
71	c	72	c	73	c	74	c	75	c
76	c	77	a	78	c	79	d	80	b
81	b	82	d	83	a	84	a	85	d
86	c	87	d	88	a	89	a	90	b
91	d	92	e	93	d	94	a	95	b
96	c	97	d	98	b	99	a	100	a
101	c	102	b	103	d	104	b	105	b
106	a	107	b	108	c	109	c	110	a
111	b	112	b	113	d	114	a	115	c

## 412 Anatomy of Flowering Plants

116	c	117	b	118	a	119	c	120	c
121	a	122	a	123	b	124	c	125	a
126	c	127	c	128	b	129	c	130	c
131	c	132	b	133	c	134	c	135	d
136	a	137	b	138	c	139	c	140	b
141	b	142	c	143	a	144	b	145	b
146	a	147	a	148	d	149	b	150	b
151	a	152	d	153	d	154	a	155	c
156	c								

## The tissue system

1	a	2	a	3	a	4	d	5	b
6	b	7	b	8	a	9	d	10	b
11	a	12	b	13	b	14	a	15	c
16	a	17	d	18	c	19	b	20	a
21	c	22	a	23	a	24	d	25	b
26	b	27	a	28	c	29	a	30	c
31	b	32	c	33	a	34	b	35	c
36	b	37	a	38	c	39	a	40	d
41	d	42	a	43	a	44	b	45	b
46	b	47	a	48	a	49	d	50	b
51	a	52	b						

## Internal structure of root, stem and leaf

1	b	2	b	3	b	4	b	5	d
6	c	7	b	8	c	9	c	10	d
11	b	12	c	13	d	14	b	15	a
16	a	17	b	18	d	19	a	20	a
21	a	22	c	23	b	24	d	25	c
26	c	27	d	28	a	29	b	30	a
31	a	32	a	33	d	34	a	35	a
36	b	37	a	38	a	39	a	40	d
41	b	42	d	43	d	44	c	45	c
46	a	47	d						

## Secondary growth

1	d	2	c	3	b	4	b	5	a
6	d	7	d	8	d	9	d	10	c
11	c	12	b	13	a	14	d	15	b
16	d	17	b	18	a	19	c	20	d
21	a	22	b	23	d	24	a	25	d
26	b	27	b	28	a	29	b	30	a
31	b	32	b	33	d	34	b	35	b
36	a	37	b	38	d	39	a	40	d
41	c	42	c	43	c	44	d	45	a
46	b	47	d	48	b	49	d	50	b
51	d	52	b	53	a	54	a	55	a
56	b	57	b	58	b	59	a	60	a

61	b	62	b	63	b	64	b	65	a
66	b	67	d	68	d	69	c	70	c

## NCERT Exemplar Questions

1	a	2	b	3	a	4	a	5	c
6	c	7	d	8	a	9	b	10	a
11	c	12	c	13	a	14	d	15	a
16	d	17	d	18	a				

## Critical Thinking Questions

1	c	2	d	3	c	4	d	5	b
6	b	7	a	8	d	9	c	10	d
11	d	12	d	13	a	14	c		

## Assertion and Reason

1	d	2	b	3	b	4	a	5	d
6	a	7	c	8	a	9	a	10	d
11	c	12	a	13	a	14	c	15	b
16	b	17	e	18	c	19	b	20	a

# Answers and Solutions

## Tissue (General)

3. (a) Companion cells are connected with sieve elements by complex plasmodesmata. The sieve tubes are syncytes and allow free diffusion of soluble organic substances. The callose also plays important role. Usually the perforations in the sieve plates are surrounded by callose. The callose is soluble and disappears when the solute is dilute so that the solute can pass from one cell to another cell through the pores
4. (a) This theory was proposed by Schmidt (1924). This theory recognizes only two zones in the apical meristems
5. (c) This concept was given by Hanstein (1870). According to this, there are 3 groups of initials in the shoot apex.
7. (d) Vessel is a long cylindrical tube like structure made of many cells, called vessel members, each with lignified walls and a large central cavity. Vessel members are interconnected through perforation in their common walls
10. (b) *Idioblasts* : Those parenchymatous cells in which waste products e.g., gum, resin, sugar, starch is accumulated.
12. (b) Collenchyma is never lignified but may possess simple pits.
14. (d) The walls of vessels are lignified and hard and not very thick. Sieve tubes have thin cellulose walls.
16. (b) Albuminous cells : These cells are storage cells which are found in pteridophytes and gymnosperms stem, they store minerals as well as starch
17. (b) Technically, wood is secondary xylem formed by vascular cambium during secondary growth.

21. (a) Internal or intraxylary phloem : It originates from procambium and is primary phloem which occurs on inner side of primary xylem. It is primary anomalous structure. e.g., Members of Apocynaceae, Solanaceae.
23. (c) Cambium represents lateral meristem of plant which has actively dividing cells.
24. (d) In sieve tubes, nucleus is present only in young stage and without nuclei at maturity.
25. (b) It is a secondary permanent tissue developed from cork cambium (phellogen) by periclinal division in the extra stellar region.
26. (a) The cells of collenchyma contain protoplasm and are living without intercellular spaces. When sclerenchyma consist of thick-walled dead cells. In the beginning the cells are living and have protoplasm but due to deposition of impermeable secondary walls (lignin) they become dead, thick and hard.
27. (b) They possess hard and extremely thick secondary walls due to uniform deposition of lignin.
28. (d) This theory was proposed by Schmidt (1924). According to this theory, shoot apex consists of two distinct zones – (1) Tunica (2) Corpus.
29. (b) Tyloses are balloon like structures develop from xylem parenchyma.
31. (a) Lateral meristems occur laterally in the axis, parallel to the sides of stems and roots. The cambium of vascular bundles (fascicular, interfascicular and extrastelar cambium) and the cork cambium (phellogen) belongs to this category
32. (c) Latex vessels found in Poppy (*Papaver*).
36. (d) In collenchyma cell walls show localized thickenings due to presence of approximately 45% pectin, 35% hemicellulose and 20% cellulose.
37. (b) Cystolith : In the epidermal cells of *Ficus bengalensis* leaves, the crystals of  $\text{CaCO}_3$  accumulate in a grape manner, called as cystolith.
38. (a) The term xylem was introduced by Nagell (1858). Xylem is a conducting tissue. Xylem consists of Tracheids, Trachea (Xylem vessels), wood fibres and xylem parenchyma.
43. (c) Collenchyma tissue is made up of elongated cells with thickening at corners.
45. (c) *Chir* is gymnosperm plant which belongs to family pinaceae of gymnosperm
47. (b) Those fibres which are associated with wood or xylem have bordered pits are known as wood fibres.
48. (c) In endodermis (starch sheath) the inner and radial or transverse wall of endodermal cells have casparian strips of suberin.
51. (d) A group of initial cells, present at the subterminal region of the growing root tip, which is protected by a root cap is called root apical meristem or root apex.
52. (a) Protoderm is the outermost layer of the apical meristem which develops into the epidermis or epidermal tissue system.
54. (d) Parenchymatous cells present between two vascular bundles give rise to interfascicular cambium after dedifferentiation.
56. (b) Saffranine stains lignified elements of the tissue.
58. (b) Haberlandt (1914) gave the term Leptome for soft walled conducting part of phloem (sieve-element).
62. (a) Maize is a monocot so phloem parenchyma absent in maize.
63. (a) These meristems occur laterally in the axis, parallel to the sides of stems and roots. This meristem consists of initial which divide mainly in one plane (periclinal) and result increase in the diameter of an organ.
64. (a) Parenchyma storage of food materials e.g., Carrot, Beet root etc.
65. (b) On the basis of origin, meristematic tissue can be classified into promeristem, primary meristem and secondary meristem.
66. (d) All are involved in primary growth of plant.
67. (a) Because such plants need much flexibility
68. (a) The parenchymatous cells are isodiametric (all sides equal) and thinwalled.
71. (c) Metaxylem consist of two larger and rounded vessels situated on the sides with the pitted tracheids in between them
72. (c) Sclereids is composed of sclerenchymatous cells, lignified walls and long tubular pits. The sclereids may be spherical, oval, cylindrical, T-shaped, dumbbell-shaped or even stellate in size.
76. (c) Sieve tube formed by end to end fusion of cells and nuclei get degenerated at maturity.
77. (a) Haberlandt in 1890 classify the primary meristem at the apex of stem of three types : Protoderm, Procambium and Ground meristem. Haberlandt (1914) introduced the new terminology for meristematic zones derived from apical meristem. They are protoderm instead of dermatogen, ground meristem instead of periblem and procambium instead of plerome.
79. (d) A bladder like structure are formed during the secondary growth and blocks the continuity of the conducting system. It is known as tyloses which found in xylem cells and ray parenchyma
86. (c) Plane of division in tunica is anticlinal and in corpus it is periclinal.
87. (d) Dermatogen is the outermost layer and it forms epidermis and epidermal tissue system.

89. (a) Tracheids possess bordered pits. Maximum bordered pits are formed in gymnospermous tracheids (helps in conduction of water).
90. (b) *Eichhornia* (water hyacinth) is a hydrophyte. So root pocket present instead of root cap.
93. (d) Intercalary meristem is responsible for increase in length. This meristem is present at the base of internodes or at the base of leaves or at the base of nodes.
94. (a) Tracheids are mainly found in gymnosperms while vessels are found in angiosperms.
95. (b) Root cap is absent in adventitious epiphytic roots of orchids, aquatic plants, parasites.
100. (a) Lignin is a deposition of cell wall.
101. (c) Companion cells are not found in pteridophytes and gymnosperms (*Pinus*) but are always present in angiosperms.
103. (d) A sieve tube is analogous to RBC, both being living but enucleated at maturity. A network of fibres of  $P_1$  and  $P_2$  protein is present in the central part of lumen of sieve tube which controls movement of materials and with callose, the sealing of pores after injury.
106. (a) Meristem possesses the capacity of division. That is why plants keep growing in length whole life time.
108. (c) Xylem fibres are two types: libriform fibres (thickwalled with simple pits) and fibre tracheids (thin walled with reduced bordered pits).
111. (b) Macrosclereids or rod cells are rod shaped elongated sclereids usually found in the leaves, cortex of stem and outer seed coats.
112. (b) Lignification makes the xylem cells thick.
114. (a) The promeristem originates from embryo and therefore, called primordial or embryonic meristem.
117. (b) The opening in vessel element walls are called perforations, which may be simple perforation or multiple perforations.
119. (c) Meristematic tissue or meristem is a group of cells which has power of continuous division.
121. (a) Intercalary meristems are present mostly at the base of node (nodal region) (e.g., *Mentha viridis*, Mint), base of internode (e.g., stem of wheat, grasses), and the base of the leaf (e.g., *Pinus*).
122. (a) Because paddy is monocot plant.
123. (b) This is present away from apical meristem in primary permanent tissue. Some workers consider it as a part of apical meristem which is separated from it by means of primary permanent tissue.
124. (c) Chlorenchyma is the modification of parenchyma or specialized parenchyma.
126. (c) Promeristem is outer primary meristem.
128. (b) When wound is deep it is healed as follows healthy cells adjacent to the wound form a mass of parenchymatous cells called callus. This callus covers the wound entirely. Thus wound is healed.
130. (c) Lateral meristem present on the lateral sides. It divides only periclinally or radially and responsible for increase in girth or diameter of stem.
131. (c) Commercial jute fibres are obtained from phloem fibres. These are sclerenchymatous fibres but because of their presence in phloem they are called phloem fibres. They are used in making ropes.
132. (b) *Pistia* is an aquatic plant in which roots are not well developed.
133. (c) Most of the xylem cells have deposition of lignin on their cell wall.
134. (c) Companion cells are found in angiosperms only. In gymnospermic plants albuminous cells are found in place of companion cells.
135. (d) Because there is no variation in protoxylem and metaxylem in cells of secondary xylem.
137. (b) At the apex of roots some cells are not dividing, this region is called quiescent centre.
140. (b) Porous wood (In angiosperms) contains mainly vessels.
143. (a) Palisade parenchyma are elongated columnar cells without intercellular spaces. These have chloroplast in them and generally arranged in two layers.
145. (b) Parenchyma containing air spaces is known as aerenchyma. It provides buoyancy to hydrophytes.
147. (a) Embryo has rapidly dividing cells.
149. (b) In tracheids if the entire surface is thickened leaving unthickened circular areas known as 'bordered pits'. The vessels lack the bordered pits.
151. (a) Tunica is outermost layer and it becomes changed into epidermis.
152. (d) Bryophytes grow by a single apical cell. Position of apical cells may either be strictly terminal or subterminal.
153. (d) Lenticels are some loosely arranged areas in the periderm. Lenticels are characteristics of woody stem. Lenticels are not found in leaves.
155. (c) According to histogen theory, apex of root is made up of dermatogen, periblem and pleurome.

### The tissue system

2. (a) Protostele term was given by Jeffrey. It is the simplest and most primitive type of stele in which central core of xylem surrounded by phloem.
6. (b) Bicolateral vascular bundle is present in members of cucurbitaceae.
7. (b) When phloem is surrounded by xylem on all sides, such V.B. are called amphivasal or leptocentric. These are found in *Yucca* and *Dracaena*.
8. (a) Root hair is outgrowth of epidermal cell.
9. (d) Branching of root is endogenous. During the branching pericycle of root becomes meristematic and protrudes to outside.
12. (b) In bicollateral vascular bundle, phloem is found on both the sides of xylem.
13. (b) Periblem is the middle layer gives rise to cortex and endodermis.
14. (a) Waxy outermost lining, which is secreted by epidermis.
17. (d) In the upper epidermis, there are some large cells found in groups, which are known as motor cells or bulliform cells.



18. (c) Ground tissue system includes — cortex, endoderm, pericycle and pith.
20. (a) Water stomata are usually present in leaves of aquatic plants.
21. (c) Raphides are found below the upper epidermis in *Nerium*.
22. (a) Protoxylem surrounded by metaxylem are called mesarch.
23. (a) Inner wall of stomatal guard cell is thick and outer wall is thin. This type of structure helps in opening and closing of stomata.
24. (d) Because *Nerium oleander* is xerophytic plant and multiple epidermis is formed to check the loss of water from leaves.
25. (b) When phloem is present on both external and internal sides of the xylem. e.g., *Marsilea*, *Adiantum*.
27. (a) Calcium oxalate substances deposited on the cuticle surface. Druse and Raphides (e.g., *Pistia*) are crystals.
30. (c) In monocot roots a thick walled endodermal cells. Just outside the protoxylem. They help in passage of water from cortex to xylem.
31. (b) Trabeculated endodermis is the characteristic feature of *Selaginella*.
32. (c) A vascular bundle having the phloem strands on both outer and inner sides of xylem is called bicollateral.
33. (a) In amphivasal vascular bundle, phloem is surrounded by xylem e.g., *Dracaena*.
35. (c) Vascular tissue is well developed in xerophytes. These plants grows in areas where water supply is inadequate. Hence they have well developed root system and vasculature.
36. (b) When cambium is absent between xylem and phloem, it is said to be closed type.
39. (a) Sunken stomata found in xerophytic plants which is adaptation for decrease the rate of transpiration.
41. (d) Vascular cambium is formed secondarily from conjunctive parenchyma cells lying just below each phloem strand. The cells of pericycle lying outside the protoxylem also become meristematic to form part of strips of cambium.
43. (a) Amphicribal (Hadrocentric) : The xylem lies in the centre and remains completely surrounded by phloem. e.g., Ferns. (*Selaginella*).
44. (b) Free floating plants float freely upon the surface of water. Stomata present on upper epidermis. e.g., *Wolffia*, *Lemna*, *Pistia* etc.
46. (b) Dorsiventral leaves are found in dicots. In dicots stomata are present in lower epidermis.
49. (d) The whole plant body is enclosed by water. Submerged plants (e.g., *Hydrilla*, *Vallisneria*, *Potamogeton*) do not have stomata.
50. (b) In roots thick walled endodermal cells are interrupted by thin walled cells just outside the protoxylem patches. These thin walled endodermal cells are called passage cells or transfusion cells.

### Internal structure of root, stem and leaf

3. (b) Velamen tissue is water-absorbing tissue which can absorb atmospheric humidity. It is present in aerial root of orchids.
4. (b) Endodermis is mostly single layered and is made up of parenchymatous barrel shaped compactly arranged cells. The inner and radial or transverse wall of endodermal cells have casparian strips of suberin.
5. (d) In between upper and lower epidermis, there is present mesophyll tissue which is undifferentiated into palisade and spongy parenchyma, but all the cells are alike.
7. (b) In monocot root, Cambium is absent in the vasculature
11. (b) Hypodermis is collenchymatous (green) in dicot stem and sclerenchymatous (non-green) in monocot stem.
12. (c) Kranz type anatomy occurs in both monocot leaves (e.g., Sugarcane, Maize and Sorghum etc.) and some dicot leaves (e.g., *Amaranthus-edulis*, *Atriplex rosea* etc).
13. (d) In dicots vascular bundles are 2 to 6
18. (d) In stems, the protoxylem lies towards the centre (pith) and the metaxylem lies towards the periphery of the organ. This type of primary xylem is called endarch. In root, the protoxylem lies towards periphery and metaxylem lies towards the centre, such arrangement is called exarch.
25. (c) Conjoint : A vascular bundle having both xylem and phloem together, is called conjoint. Collateral : A vascular bundle in which the phloem lies towards outer side and xylem towards inner side, is called collateral e.g., Sunflower.  
Collateral bundle having a cambium between xylem and phloem is said to be of the open type. e.g., Dicot stem.
28. (a) Pith is generally having thin walled parenchymatous cells, which help in storage.
30. (a) In vascular bundles of *Cucurbita* (family-cucurbitaceae), phloem is present in two patches.
31. (a) In monocot root large pith, made up of loosely arranged parenchymatous cells with abundant starch grains.
39. (a) Palisade tissue are elongated columnar cells without intercellular spaces. These cells have chloroplasts. They take part in photosynthesis.

### Secondary growth

1. (d) At the initial stage of secondary growth, cambium forms a ring like structure known as cambium ring. This ring is present in stelar and cortical region both.
3. (b) Cells of sapwood are alive and because of abundant pore spaces, movement of sap takes place through these tissues.
4. (b) Albumum is an outer light coloured zone called the sap wood which are physiologically active
5. (a) Cork cambium (phellogen) develops from outer layer of cortex. It produces secondary cortex (phelloderm) on inner side and cork (phellem) on outer side.
7. (d) Cork cambium arises as a result of the tangential division of the outer cells of pericycle.

8. (d) **Periderm** : During secondary growth in dicot stems towards the outer side cork cambium produces cork outer side and secondary cortex to inner side. The three layers (Phellem, Phellogen, and phelloderm) collectively called as periderm.
10. (c) Vascular bundles are scattered and cambium is absent in monocot stem.
13. (a) The extrastelar regions grow simultaneously. The growth of extrastelar region is initiated by the formation of cork cambium or phellogen.
16. (d) Annual rings are formed due to variation in climatic conditions of any region. Spring season and autumn season occur in temperate region, thus clear annual rings are formed.
17. (b) The correct sequence from outside towards inner side in a wood dicot stem is  
Phellem → secondary cortex → Secondary phloem → wood  
(D) (A) (C) (B)
18. (a) Growth rings (Annual rings) are distinct or sharply demarcated in the plants of temperate (cold) regions (as shmla).
23. (d) Phellem, phellogen and phelloderm are collectively called periderm.
28. (a) Hydrophytes mean plant grow in water. Hydrophytes do not show secondary growth because the vascular cambium is absent.
31. (b) Treacheary elements such as tracheids, vessels, fibres, sieve tubes formed by fusiform initials.
33. (d) Because climatic variations (autumn and spring seasons) are absent in deserts.
34. (b) All dead tissues lying outside the active cork cambium are collectively known as bark.
35. (b) **Knots** : When wounds around cells undergo rapid cell division, then wound is covered by cells but the wound is not completely healup, so in adult stem knots are established.
36. (a) Vascular cambium is a lateral meristem.
39. (a) Heartwood (duramen) is a hard and dark wood which are physiologically inactive (almost dead).
52. (b) After actual falling of leaf, the scar is exposed to air, which develops a primary protective layer by deposition of lignin and suberin on their wall.
54. (a) During the secondary growth, centrally located xylem become nonfunctional due to deposition of tannins etc. the function of conduction of water and dissolved minerals from roots is now performed by outer younger rings of secondary xylem is called sap wood or albumum.
58. (b) Vascular cambium forms phloem tissue outside. Food synthesised in the leaves move to different parts of the plant through the phloem.
61. (b) Secondary xylem is made up of scalariform and pitted vessels, tracheids and sclerenchymatous fibres (wood fibres) along with xylem parenchyma.
64. (b) In Oak (*Quercus suber*) which yields bottle cork, the cavities of cork cells are filled with air which makes the cork light in weight. It also provides thermal insulating qualities.
65. (a) Lenticels are some loosely areas in the periderm. Lenticels are characteristics of woody stem. Lenticels helps in gaseous exchange and transpiration.
66. (b) Pore like small openings are present on bark of old stem.
67. (d) Vascular cambium is made up of lateral meristem.

### Critical Thinking Questions

3. (c) Quiescent centre having low rate of cell division and acts as reservoir of active initials.
4. (d) New cells form a mass of parenchymatous cells known as callus.
5. (b) Because tunica shows only anticlinal division and it is responsible for surface growth.
6. (b) Stem of maize has water containing cavities in vascular bundles.
7. (a) The nail will be 1 meter above the soil because when tree grows in height it will not effect the base level (Tree grows in height from the apical region).
8. (d) A new variety is produced by joining parts of two different plants (with the help of cambium) is called grafting. In monocots cambium is absent hence the parts of two different plants are unable to joint each other.
9. (c) Because in sea shore area being isothermal zones, temperature is constant throughout the year, so their will be no annual ring formation.
14. (c) Alkaline pH (7.8 – 8.0) is present in phloem sap where as xylem sap is acidic

### Assertion and Reason

1. (d) Bark consists of all tissues out side the vascular cambium. Phellem, phellogen and phelloderm constitute periderm.
2. (b) Stomata are absent in submerged hydrophytes. Air chambers help in gaseous exchange,  $O_2$  liberated during photosynthesis is stored in these chambers and used in respiration,  $CO_2$  released during respiration also remain in these chambers.  $CO_2$  is used in photosynthesis.
3. (b) Cambium is a lateral meristem. Its activity causes increase in width. It is composed of fusiform and ray initial.
4. (a) Higher plants have root and shoot apices where cells are in continuous state of division. Here they can grow indefinitely. Such regions are not found in animals.
5. (d) In collateral vascular bundles phloem is situated towards outer side and xylem towards inner side and both are found on same radii, but in monocot stem vascular bundle are closed, i.e., cambium is absent.

6. (a) Disease resistant plants possess thick cuticle. Infectious organisms can not grow or invade cuticle.
7. (c) Quiescent centre is found in the centre of the root apex. Cell divisions are very few in the quiescent centre as there is very little synthesis of new proteins, RNAs and DNA. Quiescent centre may function as reserve meristem.
8. (a)
9. (a) Intercalary meristems are intercalated in-between the permanent tissues. The activities of these meristems also add to the length of the plant or its organs. They originate from the apical meristems when their portions get detached due to the growth of the organs. For example, in the grasses when the internodes complete their elongation, some cells at the base retain their meristematic activity and function as intercalary meristems. They lie just above the node.
10. (d) Apical and intercalary meristems always increase in the height of plant and lateral meristem is responsible for secondary growth (increase in girth) but secondary growth doesn't occur in monocots.
11. (c) In xerophytic leaves, spongy parenchyma is reduced. Palisade parenchyma may occur on both upper and lower sides with spongy parenchyma sandwiched between the two, e.g., *Nerium*. In *Nerium* or *Oleander*, the lower surface bears deep depressions called crypts (stomatal crypts). The crypts possess a number of cutinised hair and stomata. In other xerophytic plants, stomata occur individually and are sunken below the surface due to their being overtopped by accessory or subsidiary cells.
12. (e) Phloem transports organic food inside the body of the plant. Xylem performs the function of transport of water or sap inside the plant. Thus they form the conducting elements in the plant. Haberlandt used the term leptome for phloem and hadrome for xylem.
13. (a) The palisade mesophyll lies below the upper epidermis. The spongy parenchyma or spongy mesophyll lies between the lower epidermis and the palisade parenchyma. The spongy mesophyll cells contain chloroplasts but fewer than present in the palisade parenchyma. As the chloroplasts are more abundant in the compact palisade mesophyll cells than the loosely arranged mesophyll cells, the upper surface of the leaf appears deeper green as compared to the lower surface.
14. (c) The tracheids and vessels of the heart wood get plugged by the growth of the adjacent parenchyma cells into their cavities through the pits. These in-growths are called tyloses. Ultimately, the parenchyma cells become lignified and dead.
15. (b) A distinct layer of cuticle is present in the lower epidermis. The cuticle is, however, less developed than at the upper epidermis. The lower epidermis contains a large number of pores called stomata or stomates. They lead internally into substomatal cavities.
16. (b) In isobilateral leaves, the upper epidermis contains specialized cells, i.e., bulliform or motor cells. They are highly vacuolate and can store water, if available. However, in case of water deficiency the bulliform cells lose water and become flaccid. As a result the leaf gets rolled up to reduce the exposed surface. The bulliform cells are also useful in the unrolling of leaf during its development.
17. (e) Intercalary meristems are intercalated in between the permanent tissues. They may be present either at the base of the internode as in the stems of various grasses and wheat; or at the base of the leaf as in *Pinus*; or at the base of a node as in mint (*Mentha viridis*). Usually the intercalary meristems differ from other meristems in that they ultimately get fully used up in the formation of permanent tissues.
18. (c) Various types of plant products like oils, resins, gums and tanins are deposited in the cells of the heartwood. They are antiseptic. The heartwood is, therefore, stronger and more durable than the sapwood. It is, however, liable to be attacked by wood rotting fungi. Hollow tree trunks are due to their activity. Sapwood (outer light coloured wood) is less durable because it is susceptible to attack by pathogens and insects.
19. (b) Secretory cells are specialized parenchyma cells that produce nectar, oil, etc. Idioblasts are specialized nongreen large-sized parenchyma cells which possess inclusions or ingredients like tannins, oils, crystals, etc.
20. (a) The activity of the cambium is commonly periodic in the temperate regions and the xylem produced during one growth period constitutes a growth layer. In transverse sections of stems and roots, autumn wood (summer wood) and spring wood appear in the form of distinct concentric circles known as the annual rings. Spring wood circle and autumn wood circle constitute an annual ring. Like this, year after year, such rings in the oldest part of the tree correspond to its age.

## Anatomy of Flowering Plants

## Self Evaluation Test

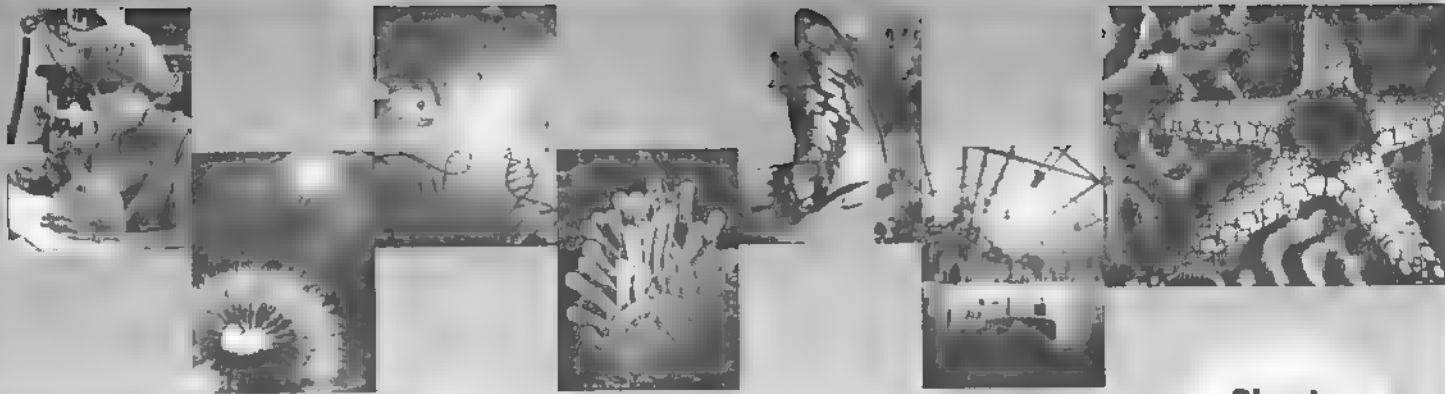
1. When strong wind blows, the plants bend down and then again become erect. This flexibility in plants is due to  
Or  
Whose living cells provide tensile and mechanical strength  
[AIIMS 1992; MP PMT 1997]  
(a) Sclerenchyma (b) Parenchyma  
(c) Collenchyma (d) Chlorenchyma
2. Quiescent centre is the zone of [CPMT 1995; Manipal 2005]  
(a) Least mitotic activity in the root apex  
(b) Least mitotic activity in the shoot apex  
(c) Maximum mitotic activity in the root apex  
(d) Maximum mitotic activity in the shoot apex
3. In the tropics there is no sharp distinction of season and the wood contains vessels of the same size in late wood and early wood. Such wood is called [JIPMER 1994]  
(a) Porous (b) Ring porous  
(c) Ring and diffuse porous (d) Diffuse porous
4. Cuticle is absent in [DUMET 2009]  
(a) Mesophytes (b) Young roots  
(c) Mature stems (d) Leaves
5. Cytologically vascular cambium (lateral meristem) differs from apical meristem by [MP PMT 2013]  
(a) Presence of vacuoles, storage materials and thin cell wall, isodiametric cells  
(b) Presence of vacuoles, storage materials and thick cell wall, isodiametric as well as radially elongated cells  
(c) Presence of vacuoles, storage materials and thick radial cell wall, isodiametric as well as radially elongated cells  
(d) Presence of vacuoles, storage materials and thin protoplasm, isodiametric cells
6. Vascular bundles are arranged in a ring in the member of family [Kerala CET 2005]  
(a) Orchidaceae (b) Iridaceae  
(c) Euphorbiaceae (d) Liliaceae  
(e) Palmae
7. The stems of hydrophytic plants are soft and weak because of the poor development of [JIPMER 2002]  
(a) Pith and supporting parenchyma  
(b) Phloem and companion cells  
(c) Xylem and supporting tissue  
(d) Cortex and endodermis
8. A concentric amphivasal (leptocentric) vascular bundle is one in which [CPMT 1993; MP PMT 2001]  
(a) Centrally located phloem is surrounded by the xylem or xylem surrounds phloem  
(b) Centrally located xylem is surrounded by phloem  
(c) Xylem is flanked by phloem on the interior and exterior side only  
(d) Phloem is flanked by the xylem on interior side only
9. Which combination of tissues act together to provide the support to the hypocotyl of a seedling [BVP 2003]  
(a) Xylem and phloem fibres  
(b) Epidermis and parenchyma  
(c) Xylem and parenchyma  
(d) Epidermis and collenchyma
10. The bicollateral vascular bundle is the characteristic feature of plants belonging to the family  
[MP PMT 1994; CPMT 1998; KCET 1999; BHU 2001]  
(a) Cruciferae (b) Liliaceae  
(c) Cucurbitaceae (d) Malvaceae
11. In a dicotyledonous stem, the sequence of tissues from the outside to the inside is [AIIMS 2003]  
(a) Phellem – Pericycle – Endodermis – Phloem  
(b) Phellem – Phloem – Endodermis – Pericycle  
(c) Phellem – Endodermis – Pericycle – Phloem  
(d) Pericycle – Phellem – Endodermis – Phloem
12. The distinct cavities (lacunae) found in a mature vascular bundle of maize stem are formed due to  
(a) Disruption of protoxylem as well as lysis of adjacent xylem parenchyma  
(b) Disruption of protoxylem alone  
(c) Lysis of xylem parenchyma  
(d) Dissolution of common wall between a few metaxylem elements and their consequent coalition
13. After preparing a transverse section out of a cut piece of a plant axis, it was seen that it has a C shaped open arch of endarch collateral vascular bundles with secondary growth. This indicates that it is a transverse section of  
(a) A dicotyledonous petiole  
(b) A dicot stem at the node  
(c) A dicot root at the point where a root branch is coming out  
(d) A phylloclade
14. Annual rings are the bands of [NCERT]  
(a) Secondary cortex and cork  
(b) Secondary vascular tissues  
(c) Secondary xylem and medullary rays  
(d) Secondary phloem and medullary rays
15. If you cut the old trunk of a tree transversely, you will observe that the outer region of secondary wood is lighter in colour. This region of wood is known as  
(a) Autumn wood (b) Sap wood  
(c) Heart wood (d) Spring wood

16. Which of the following is true for the origin of epidermis and hypodermis  
 (a) Epidermis from corpus and hypodermis from tunica  
 (b) Epidermis from tunica and hypodermis from corpus  
 (c) Both from tunica  
 (d) Both from corpus
17. Which of the following is not a part of epidermal tissue system [Kerala PMT 2010]  
 (a) Companion cells (b) Trichomes  
 (c) Root hairs (d) Guard cells  
 (e) Subsidiary cells
18. Pericycle in roots is responsible for [CBSE PMT 1990; CPMT 1994; BHU 1994, 2000, 04; MH CET 2001; DPMT 2003; KCET 2000 07; Kerala PMT 2011]  
 (a) Formation of lateral roots  
 (b) Providing mechanical support  
 (c) Formation of vascular bundle from cortex  
 (d) Formation of vascular bundle from endodermis
19. Medullary rays are made up of [AMU (Med.) 2010]  
 (a) Parenchymatous cells (b) Sclerenchymatous cells  
 (c) Tracheids (d) Fibres
1. (c) Collenchyma tissue is elastic, extensible and have capacity to expand.  
 2. (a) A zone of inactive cells is present in the central part of the root apex called quiescent centre  
 3. (d) Diffuse porous wood (primitive) : Vessels of same size are uniformly distributed throughout the growth or annual ring. e.g., *Pyrus*, *Azadirachta*, *Eucalyptus*, *Magnifera* sp., *Betula*.  
 7. (c) The stems of hydrophytic plants are soft and weak, spongy which can bend easily in each and every direction because mechanical tissue is either absent or reduced and conductive tissue is poorly developed.  
 9. (d) Mechanical strength to hypocotyl of seedling is provided by epidermis and collenchyma tissues.  
 10. (c) Bicollateral : In such vascular bundles there are two patches of phloem one on each side of xylem. In such a vascular bundles there are two strips of cambium one on each side of xylem. Cucurbitaceae (e.g., *Cucurbita*).  
 12. (b) In a completely mature vascular bundle a schizolysigenous cavity is formed by disintegration of protoxylem. These cavities are filled with water.  
 14. (b) Spring wood + Autumn wood of a year constitute annual ring. Spring and Autumn wood is the part of secondary xylem formed during spring and autumn. The amount of wood is affected by the activity of cambium.  
 15. (b) The outer young and functional part of xylem is called sap wood. The functions of conduction of water and dissolved mineral from roots is now performed by outer younger rings of secondary xylem which constitute the sapwood.  
 16. (b) According to the tunica – corpus theory epidermis is derived from outer layer of tunica and the remaining tissues are derived from remaining layer of tunica and entire corpus.  
 18. (a) In dicotyledonous roots, a well developed pericycle lies below endodermis which gives rise to lateral roots, part of vascular cambium and whole cork cambium. Pericycle functions as the site of lateral root initiation.

## Answers and Solutions

1	c	2	a	3	d	4	b	5	c
6	c	7	c	8	a	9	d	10	c
11	c	12	b	13	a	14	b	15	b
16	b	17	a	18	a	19	a		

\* \* \*



## Chapter 2.3

# Animal Tissues

A tissue may be defined as a group of one or more types of cells having a similar origin and specialized for a specific function or functions along with the intercellular material.

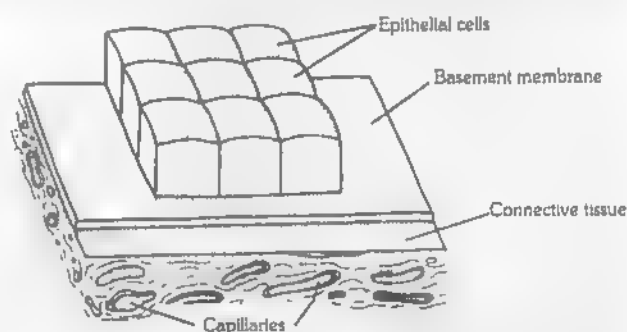
Branch of biology dealing with the study of tissue is called histology. The term 'tissue' was introduced by *Bichat* and also known as 'Father of histology'. *Mayer* coined the term 'histology' and the founder of histology is *Marcello Malpighi*. Following types of tissues are found in animals :

### Epithelial Tissue

An epithelium is a tissue composed of one or more layers of cells that cover the body surface and lines its various cavities. It serves for protection, secretion and excretion. The word 'epithelium' (G. *epl* = upon, *thele* = nipple) was introduced by *Ruysch*. They are located on the outer surfaces of organs, including the skin. They form the linings of tracts, cavities and vessels. Epithelial tissue evolved first in animal kingdom. It originate from all the three primary germ layers.

#### Structure

Cells are arranged in one or more layers, cells are compactly arranged and there is no inter cellular matrix between them. Neighbouring cells are held together by intercellular junctional complexes like desmosomes, tight junctions, interdigitations etc. The cells of lowermost layers always rest on a non living basement membrane or basal lamina. Basement membrane is made up of non cell product of epithelial tissue. It is formed of mucopolysaccharides, glycoprotein and collagen or reticular fibres. Blood vessels are absent in the epithelial tissues. However, nerve endings may penetrate the epithelium. It possesses very high capacity of renewal (mitotic cell division). The following types of modifications and junctions are found in the plasma membrane of adjacent epithelial cells to keep the cells together.



**Fig : 2.3-1** Diagram to show an epithelium with its basement membrane resting upon underlying connective tissue

**Microvilli** : These are simple and minute cytoplasmic processes arising from free exposed surfaces of the cell. They absorb material. e.g. Intestine.

**Stereocilia** : These are non-motile cytoplasmic processes. e.g. Epididymis, vas deference.

**Kinocilia** : It is contractile motile fibrous processes arising from basal granules. e.g. Oviduct, Fallopian tube.

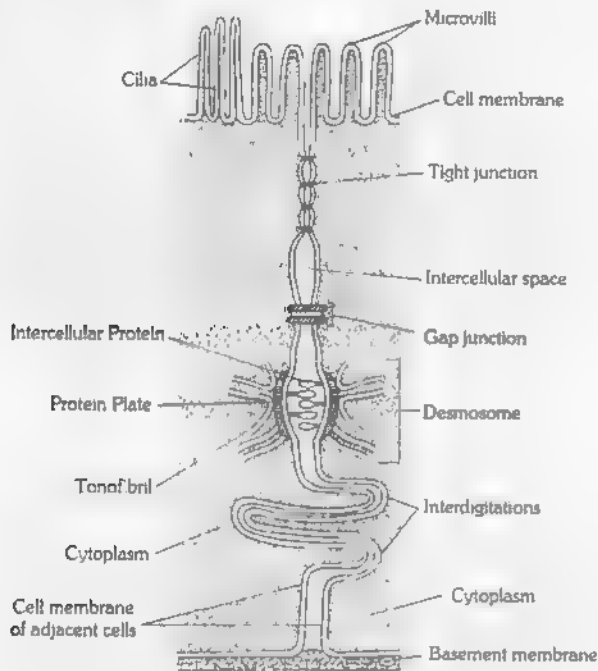
**Tight junctions (Zona occludens)** : At certain places the plasma membranes of adjacent cells are tightly packed or even fused together. e.g. Brain.

**Desmosomes** : Desmosome is present in epithelial tissue. They consist of thickened area and several fine tonofibrils extending from each plasma membrane into cytoplasm of respective cells. Macula adherens is a kind of desmosome. e.g. Vagina, Urinary bladder.

**Gap junction** : At place, the adjacent cells form ion-rich gap junctions for intercellular communication and chemical exchange. These junctions probably do not provide physical support.

**Interdigitations** : These are interwoven finger-like processes of plasma membranes of adjacent cells.

**Intercellular bridges :** These are minute projections that arise from adjacent cell membranes. The intercellular bridges make contact with one another.



**Fig : 2.3-2 Intercellular junctions between two adjacent epithelial cells**

### Functions

Epithelial tissues have a wide spread distribution throughout the body and serve several important functions –

(1) Generalized protection is the most important function of membranous epithelium. It is the relatively tough and impermeable epithelial covering of the skin that protects the body from mechanical and chemical injury and also from invading bacteria and other disease causing micro-organisms.

(2) Epithelial structures specialized for sensory functions are found in the skin, nose, eye and ear.

(3) Glandular epithelium is specialized for secretory activity, secretory products include hormones, mucous, digestive juices and sweat.

(4) The epithelium lining of the gut and respiratory tracts allows the absorption of nutrients from the gut.

(5) It is the specialized epithelial lining of kidney tubules that makes the excretion and concentration of excretory products in the urine.

(6) Ciliated epithelium moves fluid, mucus and other materials in the organs it lines.

(7) Germinal epithelium of the seminiferous tubules and ovaries produces spermatozoa and ova respectively.

(8) The ability of epithelium to regenerate quickly helps in the healing of wounds.

(9) Pigmented epithelium of retina darkens the cavity of eyeball

(10) The epithelia check the absorption of harmful or unnecessary materials.

(11) Epithelium of alveoli of the lungs brings about exchange of gases between blood and air.

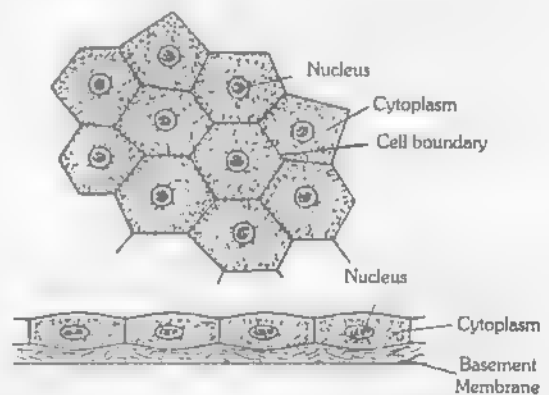
(12) Epithelium also produce exoskeletal structures such as scales, feathers, hair, nail, claws, horns and hoofs.

### Types of epithelial tissue

Mainly based on the location and functions of tissue it is of following types –

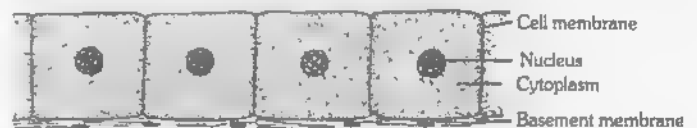
(1) **Simple epithelium** : It simple in structure and basically formed by single layer cells.

(i) **Simple squamous epithelium** : It consists of only one layer of flat, scale like cells, usually polygonal cells which are closely fitted together like the tiles of a mosaic. It is also known as pavement epithelium. e.g., It forms lining of blood vessels, lymph vessel, heart, peritoneum, pleura, Bowman's capsule, thin segment of loop of Henle and lung alveoli.



**Fig : 2.3-3 Simple squamous epithelium**

(ii) **Simple cuboidal epithelium** : The simple cuboidal epithelium is composed of one layer of cuboidal shaped cells resting on a basement membrane. The nuclei are situated centrally. e.g. the cuboidal epithelium is present in the small salivary and pancreatic ducts, thyroid vesicles, parts of membranous labyrinth, PCT, DCT, ovaries, seminiferous tubules of testes, ciliary bodies, choroid, iris of eyes, thin bronchioles and sweat gland of mammalian skin.



**Fig : 2.3-4 Simple cuboidal epithelium**

(iii) **Simple columnar epithelium** : It consists of a single layer cells, many of which have modified structure. Three common modifications are goblet, cilia and microvilli. Simple columnar epithelium is present in the stomach and intestine e.g. inner lining of gall bladder and bile duct. It also occurs in the gastric gland, intestinal glands, pancreatic lobules.

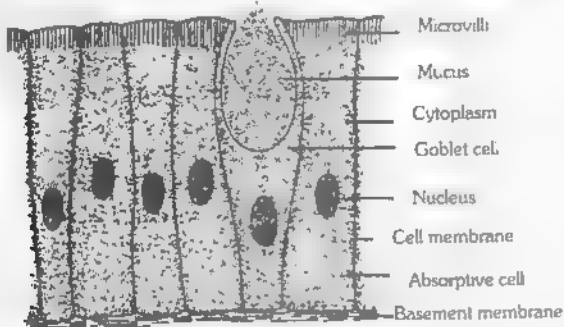


Fig : 2.3-5 Simple columnar epithelium

(iv) **Simple ciliated epithelium** : It bears numerous delicate hair like outgrowths called cilia arising from basal granules which helps to create a current to transport the materials. The ciliated epithelium is of two types :

(a) **Ciliated columnar epithelium** : It lines respiratory tract (Lower end of bronchi), fallopian tubes (oviducts), ventricles of brain (ependyma), central canal of spinal cord, tympanic cavity

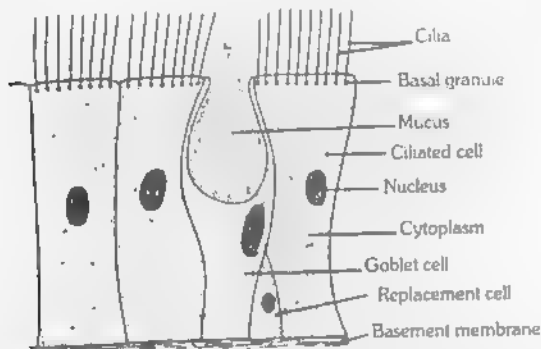


Fig : 2.3-6 Simple columnar ciliated epithelium

(b) **Ciliated cuboidal epithelium** : It occurs in certain parts of nephrons of the kidneys.

(v) **Pseudostratified epithelium** : It always consist of single layer of irregularly shaped columnar cells, touches the basement membrane. The long cells have oval nuclei however,

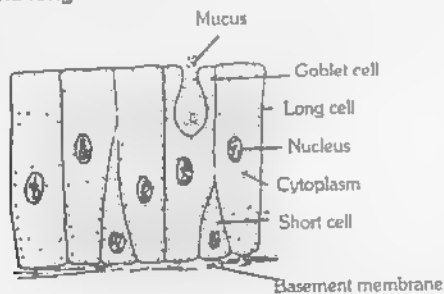


Fig : 2.3-7 Pseudostratified epithelium

Short cells have rounded nuclei although epithelium is one cell thick, but it gives the appearance of a stratified epithelium, hence it is called pseudostratified epithelium. Mucus secreting goblet cells are numerous and cilia are present. It is of two types –

(a) **Pseudostratified columnar ciliated epithelium** : It is found in the lining of trachea and bronchi (Upper)

(b) **Pseudostratified columnar epithelium** : It is found in certain segments of human male urethra and parotid salivary gland, vasa deferentia and epididymis.

(c) **Stratified squamous epithelium** : The cells in the deepest layer are columnar or cuboidal with oval nuclei. It is called germinative layer. The cells of this layer divide by mitosis to form new cells.

(2) **Compound epithelium** : It is complex in structure and basically formed by two or more than two layers of cells.

(i) **Stratified squamous keratinised epithelium** : Stratified squamous epithelium is characterized by multiple layers of cells with typical flattened squamous cells at the free or outer surface of the sheet. The presence of keratin in these cells contributes to the protective qualities of skin covering the body surface. Keratin is dead and waterproof so it protects the underlying tissues from abrasion and infection e.g. epidermis of the skin of land vertebrates

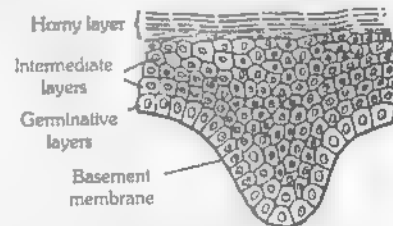


Fig : 2.3-8 Stratified squamous Keratinised epithelium

(ii) **Stratified squamous non keratinised epithelium** : Its free surface is moist, and the outer epithelial cells, unlike those found in the skin, do not contain keratin. This type of epithelium serves a protective function. It is found lining the oral cavity (buccal cavity), pharynx, oesophagus, anal canal, lower part of urethra, vocal cords, vagina, cervix (lower part of uterus) and cornea of eyes

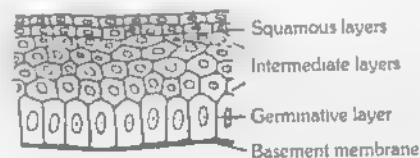
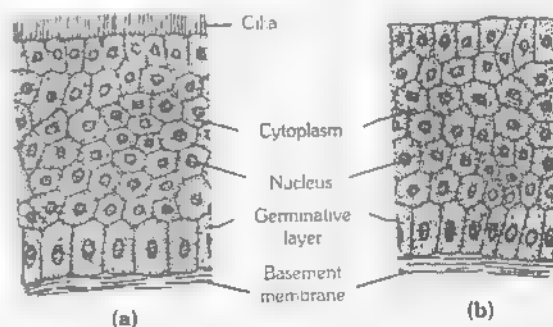


Fig : 2.3-9 Stratified squamous non keratinised epithelium

(iii) **Stratified cuboidal epithelium** : It consists of two or more rows of low cuboidal-shaped cells which are arranged randomly over a basement membrane. It is found in the sweat gland ducts, larger salivary and pancreatic ducts.

(iv) **Stratified columnar epithelium** : It is protective epithelium having multiple layers of columnar cells, only the most superficial cells are truly columnar in appearance. Epithelium of this type is rare. It is found in male urethra and in the mucous layer near the anus. It also lines mammary gland ducts and epiglottis.

Fig : 2.3-10 (a) Stratified columnar ciliated epithelium  
(b) Stratified columnar epithelium



(v) **Stratified columnar ciliated epithelium** : It lines the larynx and upper part of the soft palate.

(3) **Specialized epithelium** : This type of epithelium are specialized to perform specific activity hence, specialized in structure also. They are as follows –

(i) **Transitional epithelium (Urothelium)** : It is often ten or more layers thick. It lacks germinative layer, basement membrane. Stratified transitional epithelium is typically found in the body areas such as the wall of urinary bladder, ureter and renal pelvis. It is located in all the hollow viscera subjected to stress and protects organ wall from tearing.

(ii) **Neurosensory epithelium** : Olfactory mucosa, called Schneiderian membrane, lining of internal nares, retina of eyes and epithelial covering of tongue containing taste buds are examples of neurosensory epithelia. The sensory cells bear, at their free ends, slender “sensory hairs” to receive specific stimuli. Basely, these cells are connected, by means of synapses, with fine fibrils of sensory nerves.

(iii) **Pigmented epithelium** : The epithelial cells of the basal layer of retina contain pigment. Hence, this layer is often referred to as a pigmented epithelium e.g. – Pigmented layer of retina, iris and skin

(iv) **Germinal epithelium** : Specialized cuboidal cells capable of producing gametes as found in gonads. Germinal epithelium produces gametes e.g., ova (Female gametes) and sperms (Male gametes)

## Glands

Glandular epithelium are specialized for secretory activity. A cell, tissue or organ which secretes a useful chemical material is known as gland. Glands are made up of cuboidal epithelial cells which are more secretory. All glands arise as folding of epithelia. The golgi body in gland cells are larger and more secretory. Most of the glands of body are merocrine types. It originate from all three germinal layers. (ecto, meso and endoderm). Liver is the largest gland of the body and lined by glandular epithelium.

### Types of glands

#### (A) On the basis of number of cells

(1) **Unicellular gland** : It consist of unicellular gland cells which are called as goblet cells or chalice cells. They secrete mucous and found in mucosa of intestine and stomach. Mucous lubricates the food for easy peristalsis. Their life span is about 2–3 days

(2) **Multicellular gland** : It consist of many cells and are generally located in underlying connective tissue e.g. gastric and intestinal glands.

#### (B) On the basis of presence or absence of ducts

(1) **Exocrine gland** : These are those glands which discharge their secretory products into ducts. It is also called ducted glands or glands of external secretion. e.g. Salivary glands, Mammary glands and Tear glands.

(2) **Endocrine gland** : They are often called ductless gland, because they discharge their secretory products (hormones) directly into the blood. e.g. Pituitary gland, thyroid, parathyroid and adrenal glands

(3) **Heterocrine gland** : These are those glands which are partly endocrine and partly exocrine in function. e.g. Pancreas.

### Structural classification of exocrine glands

Multicellular exocrine glands are classified by structure, using the shape of their ducts and the complexity (branching) of their ducts system as distinguishing characteristics. Shape include tubular and alveolar (Sac like). Simple exocrine glands e.g. intestinal glands, mammalian sweat glands, cutaneous glands of frog etc. have only one duct leading to surface. Compound exocrine glands have two or more ducts e.g liver, salivary glands etc.

Table : 2.3-1

Type	Example
Simple tubular	Intestinal glands, crypts of Lieberkuhn in ileum
Simple coiled tubular	Sweat glands in man
Simple branched tubular	Gastric (stomach) gland, and Uterine gland
Simple alveolar	Mucous gland in skin of frog, Poison gland of toad and seminal vesicle.
Simple branched alveolar	Sebaceous glands
Compound tubular	Brunner's gland, bulbourethral gland and liver.
Compound alveolar	Sublingual and submandibular salivary gland
Compound tubulo alveolar	Parotid salivary glands, Mammary gland and Pancreas.

### Classification of glands on the basis of their mode of secretion

(1) **Apocrine gland** : Apocrine glands collect their secretory products near the apex or tip, of the cell and then release it into a duct by pinching off the distended end. This process results in some loss of cytoplasm and damage to the cell. e.g. Mammary glands. (Modified sweat gland)

(2) **Holocrine gland** : Holocrine glands collect their secretory products inside the cell and then rupture completely to release it. These cells self destruct to complete their functions. e.g. Sebaceous glands. In case of rabbit sebaceous glands are found in dermis of skin. Pineal body and thymus can also be considered as holocrine gland

(3) **Merocrine gland** : Merocrine glands (Eccrine or Epocrine glands) discharge their secretory product directly through the cell or plasma membrane, without injury to the cell wall and without loss of cytoplasm. e.g. Sweat glands, exocrine region of vertebrate pancreas, salivary glands and intestinal glands etc.

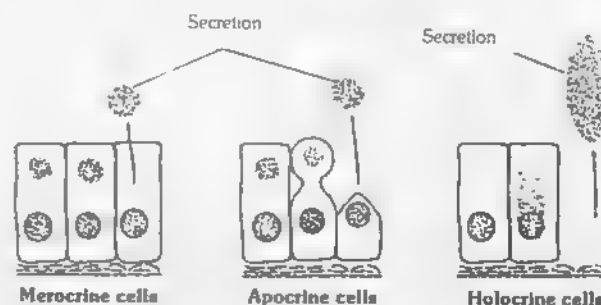


Fig : 2.3-11 Types of glands regarding the mode of secretion

**Classification of glands on the basis of nature of product**

(1) **Mucous gland** : Secret slimy mucous e.g. goblet cells, palatine gland, gland of uterus, some gastric gland and gland of colon.

(2) **Serous gland** : Produce watery secretion. e.g. pancreas, parotid, salivary gland, sweat gland and intestinal gland.

(3) **Seromucous gland** : Secrete mixed liquid. e.g. Most gastric gland, sublingual, submaxillary salivary gland, pancreas.

(4) **Cytogenic gland** : They produce cells e.g. Testis and ovary

**Connective tissue**

It connects and supports all the other tissues, the intercellular element predominating. The cellular element is usually scanty. In function this tissue may be mechanical, nutritive and defensive. It is a tissue made up of matrix (abundant intercellular substance or ground substance) and living cells that connects and support different tissues. All connective tissues in the body are formed by mesoderm.

**Structure**

There are large intercellular spaces between the cells. Intercellular spaces are filled with large amount of extracellular materials formed of insoluble protein fibres lying in an amorphous, transparent ground substance called matrix. Ageing of an animal body is associated with deterioration in its connective tissues.

**Functions**

- (1) Their chief function is to bind other tissues together in the organs.
- (2) Certain connective tissues such as adipose tissues store fat.
- (3) Skeletal connective tissues like bones and cartilages provide the body with a supporting skeletal frame work.
- (4) Fluid connective tissues such as blood and lymph transport various materials in the body.
- (5) Plasma cells synthesize antibodies, viz., macrophages. Lymphocytes ingest cell debris, harmful bacteria and foreign matter. Thus these cells of connective tissues are protective in function.
- (6) The jelly-like ground substance of connective tissues acts as shock absorber around some organs such as eye balls and kidneys.
- (7) The bone marrow produces blood cells.
- (8) Areolar tissue acts as packing material in various organs.
- (9) Collagen fibres of connective tissue help in repair of injured tissues.

**Types of connective tissues**

Connective tissue proper possess soft viscous semisolid or semi-fluid matrix. It is divided into following types :

(1) **Areolar Tissue** : Areolar tissue is loose connective tissue, possess transparent gelatinous, highly vascular and sticky matrix which have variety of cells and fibres. It allows movement of part

connected by it (Muscle and their compound). Areolar tissue mainly consist of different types of cells and fibres.

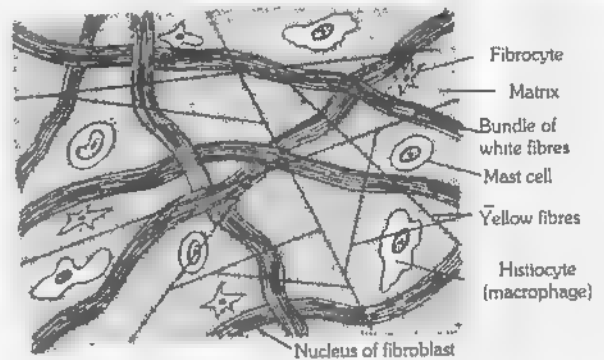
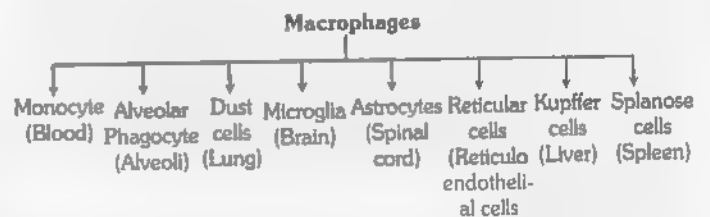


Fig : 2.3-12 Areolar connective tissue

(i) **Cells of areolar tissue** : It has following types –

**Fibroblast** : These are the most abundant cells, produces fibres, called as fibroblasts in their young active phase and fibrocytes when old and inactive. It synthesize proteins (Collagen, elastin and reticulin). These are undifferentiated mesenchyme stem cells, capable to give rise other cells of connective tissue. Collagen and elastin are formed by fibroblasts.

**Histiocytes or Macrophages or Clasmatocytes** : These are polymorphic cells. These are amoeboid cells and are main phagocytes of connective tissue. They are having most active lysosomes and phagocytise dead cells and pathogens. Macrophages remove the dead and damaged cells and clean the body so called scavenger cell. All types of macrophages take part in phagocytosis.



**Reticular cells** : Present only in the reticular tissue and stellate in appearance. Infact they are modified fibroblast producing reticular fibres.

**Mast cells** : Mast cells were discovered by *Paul Ehrlich*. They are large, irregular ovoid cells found in areolar tissue. and their number increases during allergies. It produces or secretes histamine (vasodilator), serotonin (vasoconstrictor) and heparin (anticoagulant). Histamine dilate the blood vessels in allergic and inflammatory conditions. Heparin checks the clotting of blood inside the blood vessels. Serotonin act as vasoconstrictor to arrest bleeding.

**Lymphocytes** : These are the smallest, less numerous and spherical or ovoid cells resembling lymphocytes of blood and lymph. These actively move about by pseudopodia. Their function is to form and carry antibodies. That is why, they are seen in large numbers at sites of inflammation.

**Plasma cells (Plasmacytes) :** These are usually small and rounded, superficially resembling lymphocytes but are sluggishly amoeboid and short-lived (only 2 or 3 days). These are the most potential antibody-forming cells of body presumably, mature lymphocytes (B-lymphocytes form antibody) transform into plasma cells or proliferate to form plasma cells. Plasma cells are also known as cart wheel cells.

**Fat or Adipose cells (Adipocytes or Lipocytes) :** A few, large and spherical cells occur in areolar tissue, singly or in clusters around small blood vessels. Each cell contains a large globule of fat surrounded by a thin peripheral layer of cytoplasm having a nucleus.

**Eosinophils :** These cells closely resemble the eosinophilic leucocytes of blood. These probably play a phagocytic role in inflammatory and allergic reactions.

**Chromatophores :** These are pigment cells present in specialised areas such as skin and eye. They are much branched and packed with pigment granules. They are stellate (star like) cells, which are phagocytic in nature. They phagocytose melanin producing cells and retain melanin hence they provide colour to the skin and other organs. Melanin is black pigment which protects body from ultraviolet rays of sun.

**Mesenchyme cells :** These are reserve undifferentiated cells which can be transformed into other types of cells when needed.

(ii) **Fibres of areolar tissue :** These are made up with protein and non living structures of protein produced by fibroblasts and present in matrix of connective tissue and are of three types –

**Collagenous fibres :** These are the most abundant fibrous element of areolar and other connective tissues. These are long, unbranched fibres of a soluble and shining collagen protein (tropo collagen). These fibres are more strengthful and provide maximum tensile strength. These are colourless and hyaline, yet called white fibres to distinguish them from yellow elastin fibres. Collagen protein is the most abundant protein of the body constitutes 25% the total body protein. Collagen fibre can be stained by eosin. When collagen fibres are removed from the areolar tissue they become loose and elastic. e.g. Bone, Cartilage, Ligament and tendon.

**Yellow elastin fibres :** Formed of elastin protein, these fibres are less numerous, thinner, branched, anastomosing, and of a pale yellow colour. These are very elastic and remain stretched due to tension in the areolar tissue, when broken in teased preparations, these coil and curl like tense wires. Elastin is probably the most resistant of all body proteins to chemical changes. Thousands of years old 'mummies' still have their arteries intact due to well-preserved elastin fibres. They are the orceinophilic i.e. stained by orcein.

**Reticulin fibres :** These are delicate, freely branching and inelastic fibres of reticulin protein, found interwoven, to form networks. These are very abundant in embryos, new born babies and in healing and regenerating wounds. In areolar tissues of adults, these are mostly replaced by collagen fibres, but remain abundant in lymphoid and blood forming tissues and in the stroma of pancreas, liver etc. They are stained with AgBr and AgNO<sub>3</sub>, hence are called Argentophilic or Argyrophilic. On boiling collagen and reticular fibres both convert in glue.

(2) **White fibrous tissue (Dense connective tissue) :** It is a modified form of areolar tissue. Only collagen fibres are present in the matrix and cells are mainly fibroblasts, present at the joints between skull bones and makes them immovable, also found in the dermis of higher mammals. It is of two types –

(i) **Tendons :** A tendon is non-elastic but flexible tissue consisting of parallel bundles of collagenous fibres between which rows of fibroblasts are present. It joins the muscles to bones. It also forms chordae tendinae which join the cusps of atrioventricular valves of heart with the wall of ventricles.

(ii) **Sheath :** In a sheath, the bundles of white fibres lie in a criss-cross manner. The fibroblasts are not in rows but are scattered in the areolae. The sheath forms protective covering.

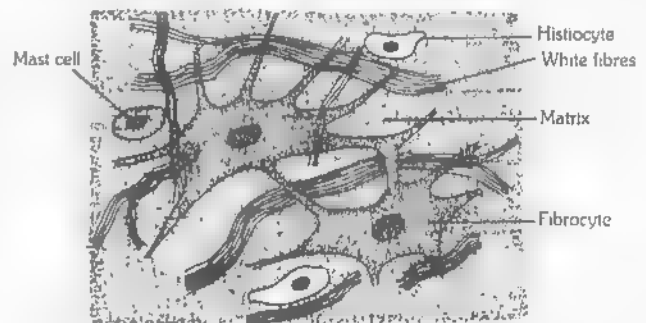


Fig : 2.3-13 White fibrous tissue

(3) **Yellow fibrous tissue (Elastic connective tissue) :** The matrix is with numerous and closely packed yellow or elastin fibres which are similar to but thicker than those of areolar connective tissue. It is elastic and flexible. It forms wall of blood vessels, lungs, true vocal chords, trachea, capsule of spleen and bronchioles. It also forms sheet in ligaments. Ligaments is a modified yellow elastic fibrous tissue and connects bone to bone.

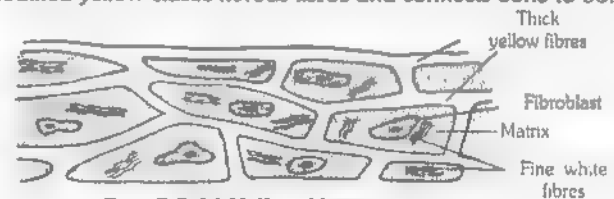


Fig : 2.3-14 Yellow fibrous tissue

(4) **Adipose tissue :** It is a modified form of areolar tissue made up of specialized large spherical fat cells (below the skin) or adipocytes. Adipose tissue chiefly acts as "Food reserves" or fat depots for storage and metabolism of lipids. Besides this, they also act as heat insulators and pressure, pull and push absorbers. Adipocytes are of two types :

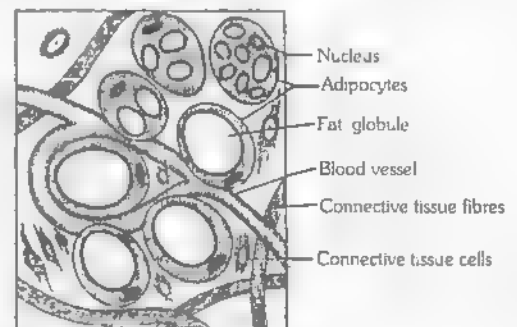


Fig : 2.3-15 Adipose connective tissue

(i) **Unilocular adipocyte (White adipose tissue)** : Common fat of body, having single large fat globule, maintain body temperature, found beneath skin subcutaneous fat panniculus adiposus, blubber of whales and elephants, hump of camel and tail of merino sheep, yellow bone marrow, around kidneys and blood vessels, mesenteries, omenta and the fat bodies of frog

(ii) **Multilocular adipocyte (Brown fat)** : Each multilocular adipocytes have several small fat globules, contain more number of mitochondria, found in rats and other rodents, polar bear, penguins, seal, walrus, in new born human babies and hibernating mammals (rats and other rodents). On oxidation it yields about 20 times more energy than ordinary fat. Brown colour is due to iron containing cytochrome pigment.

(5) **Reticular tissue** : It is a modified form of areolar connective tissue characterized by the matrix which is fluidy in nature. The matrix contains large number of stellate-shaped reticular cells, each with a number of protoplasmic processes. Reticular tissue is found in spleen, thymus, tonsils, lymph glands, liver, bone-marrow, lamina propria of mucosa of stomach and intestine. The reticular cells act as phagocytes and form a part of defence system of the body.

(6) **Myeloid tissue** : It is modification of reticular tissue. Its ground substance is plasma. It posses heavy network of reticular fibres. In active form the cells are myeloblasts. It is found in red bone marrow or haemopoietic tissue and fat reserve of yellow bone marrow

## Skeletal tissue

It provide support and surface for attachment of muscle. Skeletal connective tissue is mesodermal in origin and forms the frame work of body. It provide rigidity to body. These protect the vanous organ and help in locomotion. It is of three types : Cartilage, Bones, Notochord

### Cartilage

Cartilage is a solid but semi-rigid and flexible connective tissue. Cartilage is a nonvascular connective tissue, consisting of cells embeded in a resilient matrix of chondrin. Chondrin is a protein of cartilage. Regeneration of cartilage can occur from its peri-chondrium. Cartilage is said to be metabolically nearly inactive. In kids the cartilage cells show 2 types of growth.

(1) **Appositional or Perichondral or Secondary or Exogenous growth** : It is due to deposition of matrix and division of chondrogenic cells of periphery. It leads to growth in thickness.

(2) **Endogenous or Interstitial growth** : It is due to deposition of matrix and division in inner cells of cartilage. It leads to growth in size.

**Types of cartilage** : It is of following types –

(1) **Hyaline cartilage** : It is most primitive and glass like cartilage. Its matrix is transparent homogenous and pearly white or bluish green in colour, contain chondrin. It is slightly elastic and also known as articular cartilage because it forms the articular surface of

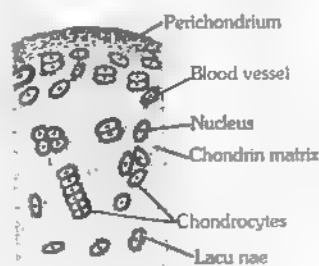


Fig : 2.3-16 Hyaline cartilage (section)

joints. Hyaline cartilage is found in trachea, larynx and bronchi, limb bones (called hyaline cap), sternum, in the hyoid apparatus nasal septum, ribs (sternal parts) larynx (cricoid, thyroid), nasal cartilage (nasal septum).

(2) **Fibro cartilage (White fibrous cartilage)** : In this cartilage, the small amount of matrix of cartilage is packed with large number of bundles of thick white (collagen) fibres. So it is toughest and less flexible. It is found in intervertebral discs and acts as shock absorber. It is also found in pubic symphysis and helps in parturition (child birth). The intervertebral discs remain contracted when the body is active, but relaxed when the body is at rest. That is why, our body becomes a bit taller during sleep and after death

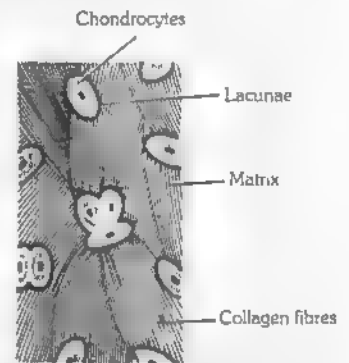


Fig : 2.3-17 Fibrocartilage White

(3) **Elastic cartilage (Yellow elastic cartilage)** : In this cartilage, the matrix is packed with yellow or elastic fibres which run in all directions to form a network. Owing to the presence of yellow fibres, It is very flexible. It gives recoiling power to structures. It is found in mammalian pinna, pharyngotympanic tube, epiglottis, some laryngeal and bronchiolar cartilages.

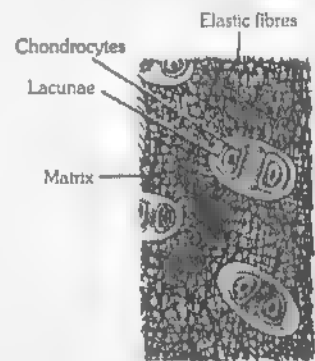


Fig : 2.3-18 Fibrocartilage Elastic

(4) **Calcified cartilage** : It is modified hyaline cartilage, It is hard and non elastic due to deposition of calcium salt-hydroxy appetite in matrix. It is found in pubis of old frog, supra-scapula of frog, quadrate cartilage of frog, shark vertebrae, in man ends of long bone, head of humerus and femur. Calcification may also occur as a regular growth process of bone due to age. It reduces elasticity of the cartilage and makes it more rigid.

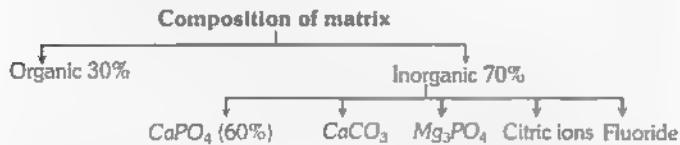
### Bone

Bone is a highly calcified (mineralized), hard and rigid connective tissue. It is the major component of adult vertebrate endoskeleton. Besides its mechanical function of supporting the body architecture and internal organs as a frame work, of protecting delicate organ like brain, heart, etc. of forming to muscles to facilitate movement and locomotion, the bone is also a metabolically dynamic tissue which functions as a homeostatic reservoir of ions of calcium, magnesium, phosphorous, etc. About 97% of total calcium of body occurs in the endoskeleton.

#### Structure of bone

**Periosteum** : It is a membrane that forms an envelop around the bone. Periosteum comprises of two distinct layers. Outer layer consist of thin white fibrous connective tissue. Inner layer consist of osteoblasts. Osteoblasts are spider like bone cells, also known as bone forming cells, because they produces new bone materials

**Matrix :** Matrix is composed of protein called ossein. The matrix forms thin plates called lamellae. Lamellae are of three types. *Haversian lamellae* (occur around Haversian canal) concentric or circumferential lamellae (inner to periosteum and outer to endosteum) and interstitial lamellae (between Haversian system). Between the adjacent lamellae are numerous small cavities called lacunae. A lacunae gives off numerous fine branching tubules called canaliculi. Each lacuna is occupied by bone forming cells called osteocyte.



**Endosteum :** It is present outer to the bone marrow cavity. Endosteum is a membrane which lines the marrow cavity. It comprises of two distinct layers, one is of fibrous connective tissue and another is osteoblasts.

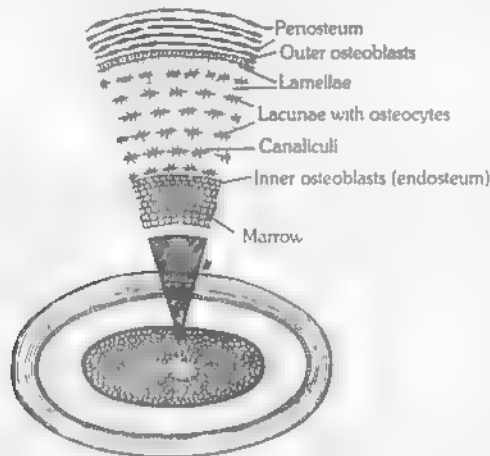


Fig : 2.3-19 T.S. of decalcified bone

**Bone marrow :** Bone marrow is a specialized type of soft, diffuse connective tissue called "Myeloid tissue". It takes part in production of blood cells hence known as haemopoietic tissue. It is composed of adipose tissue, areolar tissue and blood. It is of two types –

(1) **Red bone marrow :** Red in colour due to presence of lot of blood vessels. In foetal life and at birth present in entire skeleton. After 5<sup>th</sup> year red bone marrow is replaced by yellow bone marrow, at 20-25 years red bone marrow is present in ribs, sternum, clavicles, vertebrae, scapula, pelvis, epiphysis of humerus and femur. Produces RBCs, WBC, platelets, granular leucocytes like basophils eosinophils and neutrophils

(2) **Yellow bone marrow :** Yellow in colour and has much fatty tissue (adipose tissue), present in shaft of long bones. Produces blood cells in emergency i.e. at the time of excessive loss of blood, yellow bone marrow may be replaced by red bone marrow in anaemia

**Haversian system :** A haversian canal, its lamellae and osteocytes form a haversian system. Haversian canals are found in bone matrix of long bone, like humerus of mammals to provide extra nutrition to living part of matrix. Haversian canals contain artery and veins, osteoblasts in areolar tissue, nerves and lymph. It is also called osteon. Haversian canals are interconnected by transverse canals known as Volkmann's canals

**Types of bone cells :** Four types of cells are found in bone :

(1) **Osteoprogenitor cell :** Develops into osteoblast cell due to mitotic cell division.

(2) **Osteoblast :** Bone forming cells found in all bone surfaces. It is small cells which synthesize and secrete osteoid, an important part of ground substance. Process of osteoblast is called canaliculi.

(3) **Osteocyte :** Mature, nondividing osteoblast surrounded by matrix, lying within lacunae.

(4) **Osteoclast :** Bone destroying cells take part in reabsorption of bones, contain large amount of acid phosphatase enzyme

### Types of bone

**On the basis of their texture :** The bones are divided into two categories spongy or cancellous or tubercular bones and compact or periosteal bones.

Table : 2.3-2 Differences between Spongy bone and Compact bone

Characters	Spongy bone	Compact bone
Arrangement of lamellae	There is no regular Haversian system so have spongy texture.	Have regular Haversian system
Occurrence	In skull bones, ribs, centrum of vertebrae and epiphysis of long bones	In the shaft (diaphysis) of long bones
Marrow cavity	Broad	Narrow
Type of bone marrow	Red marrow in the spaces between lamellae	Yellow marrow in marrow cavity
Function	Marrow forms RBCs and Granular WBCs, Platelets	Marrow stores fats

**On the basis of origin of bone :** Ossification or osteogenesis is the process of bone formation. A bone is classified into four categories – Cartilaginous, Dermal, Sesamoid and Visceral bones

Table : 2.3-3 Differences between Cartilaginous, Dermal, Sesamoid and Visceral bones

Cartilaginous (Endochondrial) bone	Dermal (Intramembranous) bone	Sesamoid bone	Visceral bone
These are formed by ossification directly on the cartilages and formation involves deposition of body matter by osteoblasts and resorption by osteoclast.	These are formed by ossification in the dermis of the skin.	These are formed by ossification at the joints of the bones or on the tendon and ligament	They are formed in the soft organs.
These are elongated and hard bones. Examples : Vertebrae, humerus, femur and fibula, girdles.	These are membrane-like bones. Examples : skull bones, phalanges, clavicles.	These are small sized disc like bones. Example : patella bone (knee cap)	Examples : os cordis, os penis, os scrotoris

**On the basis of treatment :** These are of two types – Dried bone and Decalcified bone

**Table : 2.3-4 Differences between Dried bone and Decalcified bone**

Characters	Dried bone	Decalcified bone
Type of treatment	Subjected to high temperature.	Subjected to dilute solution of HCl.
Nature of matter left	With only mineral matter.	With only organic matter.
Marrow cavity	Empty.	With bone-marrow
Fate of cells	Periosteum, endosteum, osteoblasts and osteocytes are absent being killed by high temperature.	Periosteum, endosteum, osteoblasts and osteocytes all are present.
Lacunae	Lacunae present.	Lacunae absent.

#### Functions of bone

(1) **Support :** Bones form the framework of the body and contribute to the shape, alignment and positioning of the body

(2) **Protection :** Bony “boxes” protect the delicate structures they enclose,

(3) **Movement :** Bones with their joints constitute levers that move as muscle contract.

(4) **Mineral storage :** Bones are the major reservoir for calcium, phosphorus and other minerals.

(5) **Haematopoiesis :** Blood cell formation is carried out by myeloid tissue

#### Notochord

It is found in all chordate, It is replaced by vertebral column in vertebrate. Notochord is rod like structure. Notochord is made up of chordal cells.

#### Vascular tissues

It is a mobile connective tissue derived from mesoderm which consists of fibre-free fluid matrix and specialised living cells that are not formed *in situ*, can neither divide nor secrete matrix. Vascular tissue regularly circulates in the body, takes part in transport of material and performs such activities as scavenging, healing of wounds and defence against pathogens. Vascular tissue is of two types, blood and lymph,

#### Blood

In chordates, and in annelids amongst the non chordates, the blood is a red and opaque fluid of salty taste and peculiar smell. It is a little heavier than water. The study of blood is called haematology. It is red coloured liquid connective tissue which originates from the mesoderm. It reaches into the various organs through the blood vessels and transports various chemical substances between different tissues. During embryonic state, the

blood is mainly formed in the liver but little blood is also formed in the spleen and ribs. In adults, the blood is formed in the red bone marrow. The blood formation is called as haemopoiesis.

Viscosity – 4.7,  $p^H$  – 7.4

Specific gravity – 1.04 – 1.07

Volume – 5-6 litre/70 Kg or 1/13<sup>th</sup> part of total body weight

#### Plasma

It constitutes about 5% of body weight. It represents matrix of blood. Plasma is slightly alkaline and transparent. It forms 55-60% by volume of blood. Plasma contains : Water (91-92%), Solid (8-9%). Plasma solid part consists of organic (7%) and inorganic (1%) substances which are as follows :

**Organic constituents of plasma :** Some are its own constituents, while others are those which are transported by it. All these are divisible into following categories :

(1) **Plasma proteins :** Protein constitute about 7% part of plasma and remain in it as colloid particles. These mainly include albumins, globulins, prothrombin and fibrinogen.

Globulins are mainly formed by plasma cells in lymphoid organs. Other plasma proteins are mainly formed in liver. These render the plasma viscous, and maintain its osmotic pressure (7.5 atmospheric) and  $p^H$ . Prothrombin and Fibrinogen are essential for blood clotting. Albumins are mainly responsible for maintaining osmotic pressure in plasma and for osmoregulation in cells and tissue fluids. Globulins help in osmoregulation and transport of proteins and other substances, but most globulins are immunoglobulins, which act as antibodies, destroying harmful bacteria, virus and toxins in blood and tissue fluids. Some proteins, acting as enzymes, also occur in the plasma.

(2) **Digested nutrients :** These include glucose, fats, fatty acids, phospholipids, cholesterol, nucleosides, amino acids, vitamins etc. These are supplied by the blood to all cells of body.

(3) **Excretory substances :** These chiefly include ammonia collected by blood from body cells and urea, uric acid, creatine, creatinine etc., collected mainly from the liver and transported to kidneys for excretion.

(4) **Hormones :** These are secreted and released in blood by endocrine glands.

(5) **Dissolved gases :** Each 100 ml. of water of blood plasma contains about 0.29 ml of  $O_2$ , 5 ml. of  $CO_2$  and 0.5 ml of nitrogen dissolved in it.

(6) **Defence compounds :** Certain immunoglobulins or antibodies and some other substances, such as lysozyme (a polysaccharide) and properdin (a large protein) always occur in the plasma. These serve to destroy bacteria, viruses and toxic substances that may enter into the blood from outside, or from body tissues.

(7) **Anticoagulant :** Mast cells of connective tissues continuously release, in blood plasma, a conjugated polysaccharide, named heparin. The latter serves to prevent coagulation of blood while it is flowing in intact blood vessels.

**Inorganic constituents of plasma :** Chloride and bicarbonate salts of sodium are the main inorganic constituents. Traces of other salts, like phosphates, bicarbonates, sulphates and iodides of calcium, magnesium and potassium are also found. All salts constitute about 1% of plasma. These remain as ions (electrolytes) and maintain the alkalinity of plasma. A balanced quantity of salt ions in the plasma is essential for proper functioning of nervous system, muscles and other tissues.

### Blood corpuscles

Blood corpuscles form 40-50% of the blood and are of three types *viz.* Red blood corpuscles, white blood corpuscles and platelets.

(1) **Red blood corpuscles (RBCs or Erythrocytes) :** These occur only in vertebrates and are the most abundant (99%) of blood corpuscles, imparting the characteristic red colour to the blood. The shape, size and structure of RBCs vary in different types of vertebrates, but their function is same in all, namely to transport respiratory gases, especially the oxygen ( $O_2$ ).

**RBCs of frog :** Amphibian RBCs are largest amongst the vertebrates. Those of *Amphiuma* and *Proteus* are largest amongst amphibians about  $82\ \mu m$ . These are flattened and oval, disclike, but slightly biconvex due to a large oval and centrally-placed nucleus.

**RBCs of mammals :** Mammals have smallest RBCs amongst the vertebrates. Those of Musk deer are smallest amongst the mammals. Whereas the RBCs of other vertebrates are oval and nucleated, those of mammals are roughly circular (except those of the family camelidae – camels, llamas, dromedaries – which are oval in shape) and non-nucleated.

**RBCs of human :** They are about  $7.4\ \mu m$  in diameter and its thickness is 1 to  $1.5\ \mu m$ . It is pale yellow in colour but appear to be red in group. Surface area of all RBCs of a person totals about 1500 to 2000 times the surface area of the body itself.

**Structure of RBCs :** Each RBC is bounded by a dynamic, enzyme-containing plasma membrane. In human RBC, about 26.5 crore molecules of haemoglobin are packed in the intracellular framework. Water constitutes about 60% of RBC. The rest is solid. Haemoglobin forms about 34% of wet and 90% of dry weight of an RBC. Thus, 100 ml of normal human blood contains about 15 gm of haemoglobin on an average. An apparatus named haemoglobinometer is used to determine the haemoglobin contents of blood.

**Structure of haemoglobin :** Haemoglobin is a purple coloured iron (in the form of  $Fe^{+2}$ ) containing respiratory pigment of RBCs. It consists of two parts haem (5%) and globin (95%). It is conjugated protein and made up of 4 globin chains with each attached to haem molecule by Co-ordinate bond. Globin is formed of 4 polypeptide chains  $2\alpha$  chain with 141 amino acids and  $2\beta$  chain with 146 amino acid each. One-gram haemoglobin binds 1.34 ml oxygen. Amount of Hb is measured with the help of haemometer. A male has a greater amount of haemoglobin than a female. The amount of haemoglobin in normal man and woman is 14-16 gm/100 ml and 12-14 gm/100 ml respectively, while in children is slightly higher about 16.5 gm/100 ml of blood and foetus with 23 gm/ 100 ml.

**Number of RBC :** The number of RBC are counted by instrument haemocytometer. The total number of RBC per cubic mm of blood is called RBC count

Table : 2.3-5

S.No.	Organism	Number of RBCs
1	Male	5 – 5.4 million / cubic mm of blood
2.	Female	4.5 – 5 million / cubic mm of blood
3.	Infants	65 – 70 lacs/ cubic mm of blood
4.	Embryo	85 lacs/ cubic mm of blood
5.	Rabbit	70 lacs / cubic mm of blood
6.	Frog	4 lacs / cubic mm of blood

**Life span of RBC :** The life span of red blood corpuscles circulating in the blood stream varies in different animals RBC have longest life span in blood.

Table : 2.3-6

S.No.	Organism	Life span of RBCs
1	Mammals and Human	120 days or 4 months
2	Rabbit	80 days
3.	Frog	100 days
4.	New born	100 days

**Function of RBCs :** The major function of erythrocytes is to receive  $O_2$  of respiratory surfaces and then transport and readily deliver it to all cells of body. This important function is performed by haemoglobin which has a great ability to combine loosely and reversibly with  $O_2$  and hence called "respiratory pigment". Haemoglobin, in annelids, is dissolved in the plasma because of absence of red blood corpuscles. In mollusc and some arthropods, etc., a different respiratory pigment, haemocyanin is found dissolved in the plasma. This pigment is bluish due to presence of copper in place of iron.

**Haemolysis :** Due to bursting of plasma membrane of RBCs its haemoglobin comes out. This process is called haemolysis. Some fat solvent and snake venom cause haemolysis. When RBCs are placed in hypotonic solution haemolysis take place. When human RBCs are placed in pure water or distilled water they will swell and burst. Some times in haemolysis, the RBCs lose their contents by diffusion and hence maintain their emptied forms intact. These are then called "shadows" or "ghosts" of RBCs

**Rouleaux formation :** If a drop of fresh blood is placed on a slide under coverslip. RBCs adhere together by their concave surfaces like stacks or pile coins. This is called Rouleaux formation. It occurs probably due to forces of surface tension. It may also occur temporarily in blood vessels wherever circulation becomes unduly slow for some time

**ESR :** It is called erythrocyte sedimentation rate. This test is measured by "Wintrobe's tube" and "Westergren's tube" method. It is the rate of sinking/settling down of RBC in the plasma to form rouleaux. Man has lower ESR as compared to women and it is lowest in new born. Normal value of ESR in male is about 5 mm and in female 10 mm in first hour. A rise in ESR indicates the presence of infective/ destructive/ inflammatory diseases



**(2) White blood corpuscles (WBCs) or Leucocytes :**

They are nucleated, colourless and complete cells. They are bigger than RBC but their number is less. WBC shown least consistency in shape. The number of WBC is 5,000 to 10,000 per cubic mm. They are formed in red bone marrow, spleen, thymus and lymph nodes from myelocytes and the process is called as myelocoeisis. The life span of WBC is of 15 hours to 2 days. The WBC are destroyed outside the blood vessels and the process by which they come out is called as diapedesis. An increase in they number of white blood corpuscles is called leucocytosis. More than 20,000 per cubic mm. indicates some disease. A decrease below 5000/Cu.mm is called leucopenia as in typhoid fever. The leucocytes are divided into two main varieties

(i) **Granular leucocytes :** These cells develop in the red bone marrow from the same parent cells as the erythroblasts, i.e., myeloblast in the red bone marrow These are granular leucocytes of roughly spherical shape,  $10\mu$  to  $15\mu$  in diameter, actively amoeboid and containing a large number of stainable granules. Their nucleus is irregular and divided into 2 to 5 interconnected lobes. Hence, these are also called polymorphonuclear leucocytes.

(a) Neutrophils are the most abundant and, most active type of WBCs Nucleus has 3-5lobes They are phagocytic

(b) Eosinophils are phagocytic with bilobed nucleus. High eosinophil count indicates allergic conditions and parasitic infestations

(c) Basophils are nonphagocytic with 2-3 lobes of nucleus. They are also involved in allergic reactions.

(ii) **Agranular leucocytes :** They have a few non-specific or no granules in the cytoplasm and the nucleus is spherical to kidney shaped. They comprise about 25-30 % of all leucocyte and have two varieties.

(a) **Lymphocytes** Protect from pathogens and are involved in the production of antibodies.

(b) **Monocytes** are the largest corpuscles and are phagocytic

Normal DLC (Differential leucocyte count) is

Neutrophils	60-70%
Eosinophils	2-4%
Basophils	0.5-1%
Lymphocytes	20-25%
Monocytes	3-8%

(3) **Blood platelets :** These are protoplasmic disc that are found in mammalian blood (lower vertebrates have spindle-shaped cells named thrombocytes). Platelets arise as detached tips of protoplasmic processes extending from the cytoplasm of giant cells, megakaryocytes of red bone marrow. The shape is oval to round, often stellate. There are approximately 300,000 platelets in a cubic

millimetre of blood Platelets are non-nucleated. Life span is about 5-9 days.

**Coagulation or Clotting of blood**

Process of formation of blood clot is also known as blood coagulation. Normal time of blood clotting is 3 to 8 minutes. Blood clotting is checked in blood vessels by the presence of anticoagulant. When an injury is caused to a blood vessel bleeding starts which is stopped by a process called blood coagulation or clotting. This process can be described under four major stages.

I. Damaged platelets or tissue cells release thromboplastin

II. Prothrombin  $\xrightarrow{Ca^{2+}}$  Thrombin

III. Fibrinogen  $\xrightarrow{Ca^{2+}}$  Fibrin

IV. Fibrin + cells  $\longrightarrow$  Clot

Blood coagulation is helped by thrombocytes

**Stage I** is concerned with the formation of thromboplastin released from damaged tissue or platelets. Thromboplastin helps in the formation of the enzyme thrombokinase

**Stage II** involves the conversion of prothrombin into thrombin with the help of thrombokinase and calcium ions.

**Stage III** involves the conversion of a soluble protein fibrinogen in plasma to insoluble network of fibrous material called fibrin by the action of thrombin.

**Stage IV** is the formation of red solid mass called blood clot by trapping of blood cells particularly RBCs by fibrin network.

**Table : 2.3-7 Coagulation factors**

Factor	Name	Factor	Name
I	Fibrinogen	VIII	Antihemophilic factor
II	Prothrombin	IX	Christmas factor or plasma thromboplastin component (PTC)
III	Thromboplastin	X	Stuart factor or Stuart-Prower factor
IV	Calcium- ions	XI	Plasma thromboplastin antecedent (PTA)
V	Proaccelerin (Labile factor)	XII	Hageman factor
VI	Hypothetical factor	XIII	Fibrin stabilizing factor (FSF)
VII	Serum prothrombin conversion accelerator (Stable factor)		



**Functions of blood :** On basis of the above account, the general functions of blood can be briefly enumerated as follows :

(1) Blood is the fluid medium which transports different materials between various parts.

(2) The leucocytes of blood play the important role of defense by inactivating and destroying harmful toxins and invaders like bacteria, viruses, fungi and animal parasites.

(3) Blood leucocytes phagocytes and destroy cell debris and inert foreign particles in blood and tissues. Thus, these act as "scavengers" to clean the body's internal environment.

(4) Blood maintains the normal temperature of body. It prevents a sharp rise or fall in temperature which may be caused in any tissue due to abnormal rate of metabolism

(5) By coagulating at an injury, and by stimulating repairing of damaged tissues, the blood helps in rapid healing of wounds and injuries.

(6) Blood helps in the maintenance of a proper internal environment in the body by regulating the amount of salts, acids, bases and water, etc. in the tissue fluids

## Muscular tissues

Contractility and motility (movement) are fundamental properties of protoplasm. That is why, all cells possess potential motility. Contraction for motility in the cells results essentially from the interaction of two contractile proteins, actin and myosin. These tissues are obviously responsible for movements of organs and locomotion of the body in response to stimuli. These develop from embryonic mesoderm except for those of the iris and ciliary body of eyes, which are ectodermal in origin. About 40% to 50% of our body mass is of muscles. The muscle cells are always elongated, slender and spindle-shaped, fibre-like cells. These are, therefore called muscle fibres. These possess large numbers of myofibrils formed of actin and myosin. Muscle cells lose capacity to divide, multiply and regenerate to a great extent. Study of muscle is called myology. Types of muscle are following –

### Striated or striped muscles

Most muscles of body are striated. These generally bring about voluntary movements under conscious control of brain and, hence, called voluntary muscles. Most of these are inserted at both ends upon bones in different parts of the body. Hence, these are also called skeletal muscles. Movements of limbs and the body solely depend upon these muscles. Hence these are also called somatic muscles. These are also called phasic type of muscles, because contraction in these is rapid, but brief and fatigue occurs quickly

**Fine structure of striated muscle fibres :** Striated muscle fibres shows transverse striation in the form of regular alternate dark A (anisotropic) and light I (isotropic) bands. The 'A' band contains about  $120\text{\AA}$  thick and  $1.8\text{ }\mu$  long "myosin filaments". The I band contains about  $60\text{\AA}$  thick and  $1.0\text{ }\mu$  long "actin filament" which are twice as many as myosin filaments. Each I band is divided into two equal halves by a thin, fibrous and transverse zig-zag partition, called 'Z' band ('Z' disc) or Krause's membrane. Each segment of a fibril between two adjacent 'Z' bands is called a sarcomere. It is  $2.3\text{ }\mu$  long in uncontracted mammalian striated fibres. A slender transverse line, the 'M' or Hansen's line is visible in middle of each 'A' band. The major, middle region of 'A' band is comparatively lighter, but its terminal parts appear darker. The middle lighter region is called 'H' zone. Due to the geometric bonding pattern, the end of each myosin filament is, thus, encircled by the ends of six actin filaments (hexagon), while the end of each actin filaments is encircled by the ends of three myosin filaments (trigon).

**Ultrastructure of myofilaments :** At the molecular level, each myosin filament is composed of about 500 thread-like myosin molecules. Three different kinds of proteins participate in the composition of actin filaments. The major part of an actin filament is a coiled double helical strand whose each arm is a linear polymer of small and globular molecules (monomers) actin protein. Another coiled double helical, but thinner, strand runs along the whole length of actin strand. Each arm of this strand is a polymer of fibre-like molecules of tropomyosin protein. The third protein is troponin.

**Working of striated muscles :** H.E. Huxley and A.F. Huxley in 1954 proposed a theory to explain the process of muscular contraction. This theory is known as 'sliding filament theory'. It was observed that when a fibril contracts, its 'A' bands remain intact, while the 'I' bands progressively shorten and eventually disappear when the fibril has shortened to about 65% of its resting length. At this stage 'H' zones also disappear because the actin filaments of both sides in each sarcomere reach, and may even overlap each other at the "M" line, and the 'Z' lines now touch the ends of myosin filaments. It was further observed that if a fibre is mechanically stretched, the zones of overlap between thick and thin filaments are shorter than in resting condition, resulting in wider 'H' zones. These observations led Huxley to propose that shortening of the fibrils in contraction is brought about by sliding movement of actin filaments over myosin filaments towards "M" line by means of rapidly forming and breaking cross bridges or ratchets at the spurs of myosin filaments. Thus, the sarcomere were recognised as the 'ultimate units of contraction'.

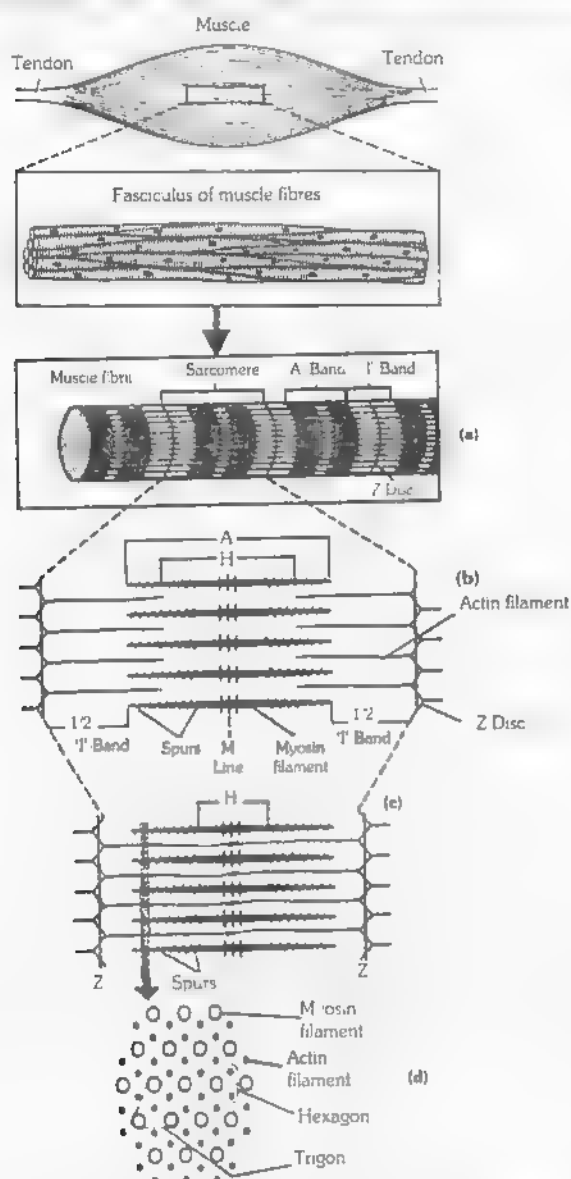


Fig : 2.3-20 Ultrastructure of a relaxed striated myofibril (a) a sarcomere (b) & (c) a contracted sarcomere: (d) T.S. through terminal part of a A band

### Smooth muscles

These are called smooth, plain nonstriated involuntary or unstriped muscles due to absence of striations. These occur in the walls of hollow internal organs (alimentary canal, gall bladder, bile ducts, respiratory tracts, uterus, urinogenital ducts, urinary bladder, blood vessels, etc.), in capsules of lymph glands, spleen etc., in iris and ciliary body of eyes, skin dermis, penis and other accessory genitalia, etc. There is no connection of these muscles with bones. Smooth muscles of skin dermis, called arrector pili muscles, are associated with hair roots, and are responsible for flesh (erection of hairs). Those of penis form a muscular network which helps in its erection and limping.

**Structure :** Smooth muscle fibre is unbranched goose-spindle shaped, uninucleated and has no sarcolemma. Contraction is slow, involuntary under the control of ANS. Functionally smooth muscles are of two types –

(1) **Single-unit smooth muscle :** Single unit smooth muscle fibres are composed of muscle fibres closely joined together, contract as a single unit. e.g., urinary bladder, gastrointestinal tract, small arteries and small veins

(2) **Multi-unit smooth muscles :** Are composed of more independent muscle fibres, contract as separate units e.g. – hair root muscle, muscles on the wall of large blood vessels, ciliary muscles, muscles of iris and bronchi.

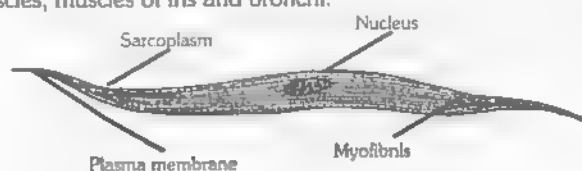


Fig : 2.3-21 Smooth muscle

### Cardiac muscles

Heart wall (also the wall of large veins just where these enter into the heart) is made up of cardiac muscles and, hence, called myocardium. Structurally, these muscles resemble striated muscles but, functioning independently of the conscious control of brain, these are involuntary like the smooth muscles. Cardiac muscle cells of fibres are comparatively shorter and thicker, cylindrical, mostly uninucleate with a central nucleus, somewhat branched and covered by a sarcolemma.

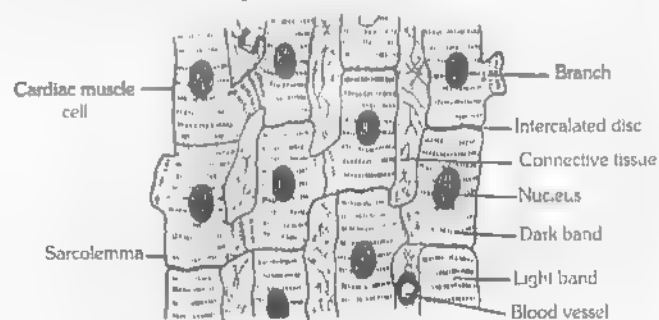


Fig : 2.3-22 Cardiac muscle fibres

### Characteristics of a muscle

**Antagonistic muscles :** The striated muscles occur in antagonistic pairs; one pulls a bone in one direction, while the other pulls it back in reverse direction to its normal position. For example, the biceps muscle, extending from shoulder to radius, bends or flexes the arm at the elbow, whereas the triceps extending from ulna to the shoulder, straightens the arm. Thus, biceps is a flexor and triceps an extensor for bending the arm

**Single twitch :** Twitch is a rapid, jerky response to a stimulus. When a muscle receives a single excitation impulse, it responds by a sudden partial contraction (twitch) lasting for about 0.5 second in man. Each twitch is followed by a refractory period during which the muscle does not respond to next stimulus. The refractory period is, however, so short (0.002 second) that the muscle can respond to the second stimulus while still in contraction phase in response to the first stimulus.

**Tetanus :** Generally, whole muscles contract, not in a single twitch, but in sustained contractions evoked by a series of nerve impulses reaching them in rapid succession. Such a sustained contraction is called tetanus. Described above should not be confused with the disease of "tetanus" (lock jaw) caused by tetanus.

bacillus. This disease is characterised by abnormal muscular contractions. Nor it should be confused with "tetany" which is muscular spasm occurring due to deficiency of parathyroid hormone.

**Muscle tone or "Tonus" :** Even at rest the striated muscles normally remain in a state of mild sustained partial contraction to maintain the body posture. This is called muscle tone. It is a mild state of tetanus.

**Paralysis :** When supply of motor impulses to a muscle is completely cut off due to destruction, either of the control centres in brain, or of the concerned motor nerves, or due to blocking of myoneural junctions by the use of certain drugs, the muscle function is completely impaired. This is called paralysis of the muscle.

**Muscle fatigue :** A muscle that has contracted many times at short intervals, exhausts its store of ATP and glycogen and accumulates lactic acid. Hence its contractility gradually decreases and finally stops.

**Oxygen debt :** During active work or exercise, the rate of oxygen supply by the lungs falls short of the requirement of the muscles. Hence, lactic acid accumulates in the muscles and the breathing gradually becomes hard to enhance  $O_2$  intake by the lungs. This is called oxygen debt.

**Involuntary action of skeletal muscles :** Muscles are capable of utilizing, in their mechanical work, only about 20% to 40% of energy liberated from glucose. The unutilized energy is lost as "heat" dissipated into the environment. This heat helps in maintenance of body temperature. "Shivering with cold" in winter is caused by a quick involuntary reaction of striated muscles.

**Rigor mortis :** Rigidity that develops in the muscles after death is known as rigor mortis. It is due to permanent irreversible contraction, establishment of permanent link between actin and myosin and also fall in the concentration of ATP molecules.

**Cori's cycle :** Lactic acid is transported by blood to liver and there it is converted to glycogen through Cori's cycle.

**Contraction period :** Time taken in sliding of filament is called contraction time. (10 to 100 milli second)

**Relaxation time :** It is time taken in relaxation of fibre i.e. active transport of calcium from sarcoplasm to cisternae. (10 to 100 milli second)

**Refractory period :** It is time in a muscle or nerve fibre when they are non responding to second stimulus. Infact in this period there is temporary loss of excitability. Refractory period for skeletal and cardiac muscle is 5 and 300 milli second respectively.

**Hypertrophy and Atrophy of muscles :** Muscles which are put to excessive work become thick and strong. This is called their hypertrophy. Conversely, if certain muscles are not used for a long period, those become thin and weak. This is called their atrophy (disuse atrophy). Cardiac muscle have a poor regenerative power.

## Nervous tissue

A most complex tissue in the body, composed of densely packed interconnected nerve cells called neurons (as many as  $10^{10}$  in the human brain). It specialized in communication between the various parts of the body and in integration of their activities.

Nervous tissue is ectodermal (from neural plate) in origin. It forms the nervous system of the body which controls and coordinates the body functions. There is no intercellular matrix between neurons. These have permanently lost the power of division as have no centriole and have minimum power of regeneration. So these cannot be cultured in vitro. Irritability is the main function of nervous tissue.

**Composition of nervous tissue :** Nervous tissue is formed of four types of cells :

- |                           |                           |
|---------------------------|---------------------------|
| (1) Neurons (nerve cells) | (2) Neuroglia             |
| (3) Ependymal cells       | (4) Neuro-secretory cells |

### Neurons

A neuron is a nerve cell with all its branches. Neuron is formed from neuroblast. It is the structural and functional unit of nervous system. It is the longest cell of the body.

(1) **Cyton :** It is also called perikaryon or soma or cell body. Its granular cytoplasm is called neuroplasm which has following structures :

(i) A large, spherical, centrally placed nucleus with a single nucleolus.

(ii) Numerous fine threads called neurofibrils for the conduction of nerve impulses.

(iii) A number of small, basophilic granules called Nissl's granules formed of rough endoplasmic reticulum with ribosomes and are sites of protein synthesis.

(iv) Neuroplasm has large number of mitochondria to provide high energy for impulse conduction.

(v) Neuroplasm may have melanophores with melanin pigment and lipochromes with orange or yellow pigment.

(vi) A mature neuron has no centriole, so it cannot divide.

(vii) A "**Barr body**" is often seen abutting against the inner surface of nuclear membrane of cytons in females. This has been proved to be a transformed 'X' chromosome.

(viii) Certain neurons having flask-shaped cytons and called purkinje cells, occur in the cerebellum of the brain.

(2) **Neuron processes :** The processes of neurons, called neurites, extend varying distances from the cyton and are of two types – dendrites or dendrons and an axon or axis cylinder (neuraxon).

(i) **Dendron :** These are several short, tapering much branched processes. The dendrites contain neurofibrils, neurotubules, Nissl's granules and mitochondria. They conduct nerve impulse towards the cell body.

(ii) **Axon :** This is a single very long, cylindrical process of uniform diameter. It arises from a conical projection, the **axon hillock**, of the cyton. The axon contains neurofibrils and neurotubules but lacks Nissl's granules. Axon is usually branched only terminally into slender branches called telodendria. The latter have knobbed ends called endbulbs or axon terminals or buttons or synaptic knobs or end plates. The synaptic knobs contain mitochondria and secretory vesicles.

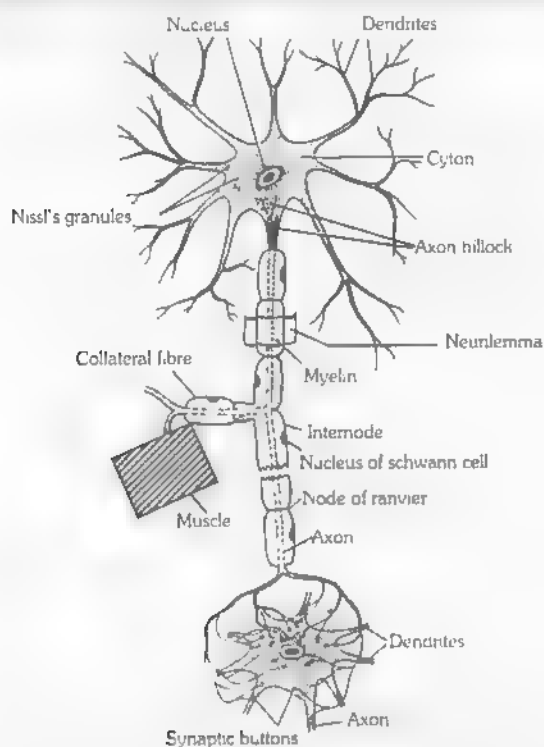


Fig : 2.3-23 An Enlarged Neuron and its synapses with another Neuron

**Types of neurons :** Neurons are divided into different categories on different basis.

(1) **On the basis of functions :** Neurons are divided into three categories :

**Sensory (afferent) neurons :** These are found in sense organs. Their dendrons receive the nerve impulse from the nerve process of the receptor cell while their axon forms the synapse with dendron of the next neuron. These may be naked or encapsulated e.g. olfactoreceptors and gustatoreceptors

**Internuncial neurons :** These are located in the dorsal horn of the spinal cord. These are called association neurons (when their axon synapses with the dendron of motor neuron of same side) or commissural neuron (when their axon synapses with the dendron of motor neuron of opposite side).

**Motor (efferent) neurons :** These are always present in the ventral horn of the spinal cord. Their axon ends into the muscle fibres or glands cells. These conduct the nerve impulses to the effector organs which respond to the stimuli

(2) **On the basis of number of nerve processes :** Neurons are of three types –

**Unipolar neurons :** In these neurons, only one nerve process arises from the cyton which acts as axon but there is no dendron. These are found only in early embryos. The unipolar neuron of the adult gives rise to a single nerve process, which immediately divides into a dendron and an axon. Such unipolar neurons are called pseudo-unipolar neurons. These are found in the dorsal root ganglia of spinal nerves and in the roots of V, IX and X cranial nerves.

**Bipolar neurons :** In these neurons, the cyton gives rise to two nerve processes out of which one acts as an axon while other acts as a dendron. These are found in the olfactory epithelium of nasal chamber and retina of eye. These may be isopolar or heteropolar (dendrons being irregularly branched). Ganglia of VIII cranial nerve

**Multipolar neurons :** In these neurons, the cyton gives rise to several nerve processes out of which one acts as an axon while remaining nerve processes act as dendrons. These are found in the central nervous system and the ganglia of autonomic nervous system of adult.

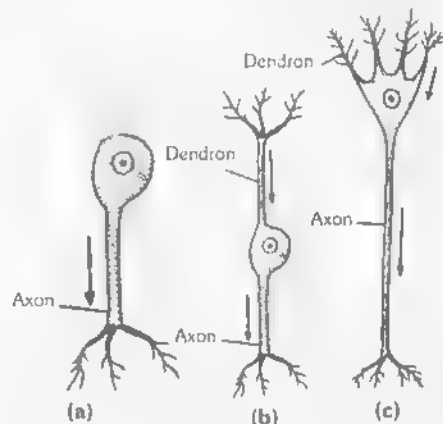


Fig : 2.3-24 Types of Neurons (a) Unipolar; (b) Bipolar; (c) Multipolar

### Neuroglia or Glia cells

Neuroglia consists of the supporting and packing cells found in the brain, spinal cord and ganglia. These are non nervous cells. These are ten times more numerous than neurons. In some parts of body the neuroglial cells are called by certain other name such as muller cells in retina, pituicytes in posterior pituitary gland and satellite cells in ganglia.

**Types :** The neuroglia cells are of three types –

(1) **Astrocytes :** These are large sized and star-shaped cells with numerous processes which form blood brain barrier therefore only located in brain

(2) **Oligodendrocytes :** These have a few branched processes which resemble the dendrons of the neurons. Forms myelin sheath around CNS Axon, example schwann cells.

(3) **Microglial cells :** These are small sized and spindle-shaped. The microglia cells act as the defensive phagocytes in central nervous system. They arise from the monocytes.

### Functions

(1) These are capable of division and help in wear and tear of the central nervous system

(2) These insulate the adjoining neurons and prevent the lateral transmission of impulses

(3) These provide nutrition to the neurons

(4) These act as phagocytes and eat up the microbes.

(5) These help in memory processes

(6) They act as Blood brain barrier (BBB) i.e. they inhibit contact between neuron and blood, along with endothelium of capillary. The exchange of material between blood and neuron is always through these neuroglial cells i.e., they are mediator.

#### Ependymal cells

These are cuboidal and ciliated epithelial cells which line the cavities of brain (ventricles) and spinal cord (central canal). These form an epithelium called ependyma. Ependymal cell for circulation of CSF

#### Neurosecretory cells

These are special type of neurons of the hypothalamus of brain. These are endocrine in function and secrete neurohormones which are carried by the blood of hypophyseal portal system to anterior lobe of pituitary gland and stimulate the secretion of their trophic hormones e.g., TSH, STH, FSH, LH, ACTH, etc.

#### Nerve fibres

Axon or dendron of a nerve cell covered with one or two sheaths is termed as nerve fibre. The nerve fibres are of two types – medullated or myelinated and non medullated or non myelinated regarding their structure.

(1) **Medullated nerve fibres** : A medullated nerve fibre typically consists of a central core, the axis cylinder, or neuraxis, surrounded by two sheaths : inner thick medullary sheath and outer thin neurilemma.

(i) **Axis cylinder** : The axis cylinder is simply the axon or dendron of a nerve cell. It contains longitudinal neurofibrils and mitochondria in its neuroplasm, called axoplasm, limited by cell membrane termed axolemma. It is the axolemma that conducts the nerve impulses.

(ii) **Medullary sheath** : The medullary sheath is composed of a shining, white, fatty substance called myelin. This sheath perhaps serves as an insulating layer, preventing loss of energy of the nerve impulse during its passage along the fibre. It causes saltatory conduction of impulses. The medullary sheath is continuous around the fibres in the central nervous system, but in the fibres of the peripheral nerves it is absent at certain points known as the Node of Ranvier. The part of a nerve fibre between two successive nodes is termed the internode.

(iii) **Neurilemma** : The neurilemma consists of tubular sheath cells (Schwann's cells) placed end to end. The neurilemma is continuous over the Nodes of Ranvier. The function of the Schwann's cells is to produce the myelin sheath around the neuraxis. The medullated nerve fibres within the brain and spinal cord lack neurilemma. Instead, they have an incomplete covering of neuroglia cells, which probably produce the myelin sheath. Neurilemma present around the peripheral nerve fibres enables them to regenerate after injury. Nerve fibres in the brain and spinal cord do not regenerate after injury due to lack of neurilemma. The medullated nerve fibres occur in the white matter of the brain and spinal cord and in the cranial and spinal nerves.

(2) **Non medullated nerve fibres** : A non medullated nerve fibre consists of an axis cylinder enclosed by neurilemma and connective tissue. These fibres appear grey in colour in the fresh state. The non-medullated nerve fibres occur in the autonomic nerves.

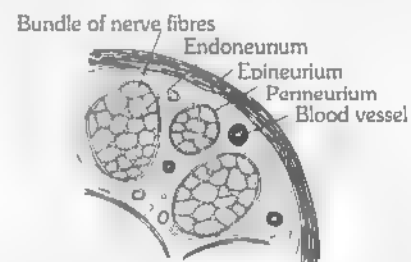
**Table : 2.3-9 Difference between medullated and non-medullated nerve fibre**

S.N	Characters	Medullated nerve fibres	Non-medullated nerve fibres
1.	Occurrence	Found in white matter of brain, spinal cord, cranial and spinal nerves	Found in grey matter of brain and spinal cord, and in autonomic nervous systems
2.	Sheaths	Neuraxis covered by inner medullary sheath and outer neurilemma	Neuraxis covered by only neurilemma. Medullary sheath is absent
3.	Nodes of Ranvier and internodes	Present	Absent
4.	Diameter	More	Less
5.	Colour	White	Grey
6.	Speed of conduction of nerve impulses.	Faster due to saltatory conduction of nerve impulses	Slower
7.	Collateral branches	Present	Absent

#### Nerves

The nerves are thread like structures extending between the central nervous system and the receptor or effector organs of the body. These conduct the nerve impulses to and from the central nervous system.

Each nerve is formed of several bundles of nerve fibres, called fasciculi. Each nerve fibre of the bundle is covered by a thin sheath of connective tissue called endoneurium, while each fasciculus is enclosed by another sheath of white fibrous connective tissue called perineurium. All the fasciculi are held together by the connective tissue and are enclosed by a thick coat of white fibrous connective tissue called epineurium. On average, a nerve contains about twice as many unmyelinated fibres as myelinated fibres.



**Fig : 2.3-25 T.S. of Nerve**

**Types of nerves** : The nerves are of three types according to the nature of the nerve fibres they are composed of –

(1) **Sensory or afferent nerves** : The nerves with sensory fibres are called sensory nerves. It brings the impulse towards the central nervous system. Example – Olfactory, optic and auditory nerves (I, II, VIII)

(2) **Motor or efferent nerves** : The nerves having efferent fibres are termed motor nerves. It carries the impulses away from the central nervous system. Example – Oculomotor, Pathetic and abducens nerves (III, IV, VI)

(3) **Mixed nerves** : Some nerves have both afferent and efferent fibres. These are known as mixed nerves. Example – Trigeminal, facial, glossopharyngeal and vagus nerves (V, VII, IX, X).

## Tips & Tricks

- ✎ The brown adipose tissue in human is restricted till third month of post natal life.
- ✎ Mucoid tissue – An embryoid tissue found in umbilical cord also called wharton's jelly. It is most primitive type of tissue, found in vitreous humour of eye and cock's comb
- ✎ Plasma cells are also called as "Cart wheel cells".
- ✎ The term "blubber" refers to subcutaneous deposition of fat in whales.
- ✎ Ligamentum flava – connects adjacent vertebrae and the ligaments between the phalanges, fingers and toes.
- ✎ Ligamentum nuchae – Found in the neck of quadrupeds to bear the weight of head when grazing.
- ✎ Teeth are made up of dentine (bone) and its crown is covered by enamel, which is the hardest substance of the body.
- ✎ Astronauts pass out calcium in their urine due to faster breaking down of bones, due to absence of gravitational pull
- ✎ Hardening materials in bones are mainly phosphate of calcium and magnesium
- ✎ Strongest cartilage is fibrocartilage due to collagen fibres.
- ✎ Diploic bone – Bone with compact surfaces and cancellous middle e.g., skull bone, vertebrae
- ✎ Calcination – Process of burning of bone till it becomes white
- ✎ Beside calcium phosphate (major constituents) the bones contain potassium, magnesium hydroxide.
- ✎ Study of cartilage is called chondrology
- ✎ Study of bone is called osteology.
- ✎ Long bones possess pits of Howship
- ✎ Normal blood glucose level is 90 – 120 mg/100 ml.
- ✎ Strontium – 90 is the chemical which causes damage to WBC, bone marrow, spleen, lymph nodes and lungs
- ✎ Bone marrow is absent in birds due to Pneumatic bones
- ✎ Granulocyte are formed inside Red bone marrow
- ✎ Haemocytometer is used for red cell counting
- ✎ Phagocytosis was first of all seen by Metchnikoff.
- ✎ Blood doping or blood boosting is the transfusion of one's own blood or frozen RBC to increase haemoglobin content to carry more oxygen.
- ✎ Spleen also acts as "graveyard" of RBC. If spleen is removed than filtration of dead RBC will stop
- ✎ Polycythemia – Abnormal rise in number of RBC
- ✎ When muscles contract they have squeezing effect on veins running through them. It is termed as muscle pump

- ✎ T-tubules are present in sarcolemma near the junction between A-band and I-band.
- ✎ Tongue muscles and muscles of upper part of oesophagus are striated muscles, but without any bone.
- ✎ Cholesterol concentration is highest in cardiac muscle.
- ✎ Phospholipids concentration is maximum in cardiac muscle.
- ✎ The muscles change gradually from voluntary to involuntary in the upper part of oesophagus
- ✎ Lohman Reaction :  $\text{ADP} + \text{Phospho Creatine} \rightarrow \text{ATP} + \text{creatine}$
- ✎ Chronaxie is defined as the shortest duration of stimulus required to excite a tissue by a current strength.
- ✎ Painful contractions of muscles is called muscle cramp.
- ✎ Total number of muscles in human body is 639
- ✎ Largest muscle is gluteus maximus (Buttock muscle).
- ✎ Smallest muscle is stapedius.
- ✎ Longest muscle is sartorius.
- ✎ Papillary muscles are associated with heart.
- ✎ Gastrocnemius (calf muscle) is the muscle of shank.
- ✎ Pectoralis major is flight muscle in bird
- ✎ Latissimus dorsi is the muscle of shoulder.
- ✎ Ciliary muscle is associated with eye-change focal length of lens
- ✎ Maximum muscles in back region i.e. 180
- ✎ Minimum muscles in Neck region i.e. 32
- ✎ Muscles in head region are 53
- ✎ Masseter – Lower jaw, the strongest muscle in the body.
- ✎ Rectus abdominis – Longest visceral muscle found in abdomen.
- ✎ Myology – Study of muscles.
- ✎ Myogram – Recording of muscular contraction.
- ✎ Muscular dystrophy – A hereditary disease of muscle
- ✎ Poliomyelitis – Viral disease that weakens the muscles.
- ✎ The value of resting membrane potential is – 60 to – 90 mV
- ✎  $\text{Na}^+$  and  $\text{K}^+$  Ions are required for nerve conduction.
- ✎ GABA is slow neurotransmitter substance
- ✎ Synapse is a junction between dendrites and axons ends.
- ✎ Neuroglial cells differs from neurons in having no Nissl's granules.
- ✎ Nerve fibres are different from the muscles fibres due to the presence of dendrites
- ✎ Branched ends of nerve cells are called telodendria which establish the functional contact with other nerve cell this connection is called synapse
- ✎ Most of the neurons of our body are multipolar.
- ✎ Nissl's bodies are absent in axon and axon hillock.



## Ordinary Thinking

### Objective Questions

#### Epithelial tissue

- Name the type of tissue that form gland  
[NCERT; Odisha JEE 2008; MP PMT 2010]  
(a) Epithelial (b) Muscular  
(c) Squamous (d) Cuboidal
- In thyroid follicle which type of epithelial tissue is present  
[Odisha JEE 2008]  
(a) Squamous (b) Cuboidal  
(c) Transitional (d) Columnar
- Stereocilia occur in [AMU (Med.) 2010]  
(a) Pseudostratified columnar epithelium of trachea  
(b) Columnar epithelium of stomach  
(c) Stratified columnar epithelium of pharynx  
(d) Pseudostratified columnar epithelium of epididymis
- Skin is a [CPMT 2010]  
(a) Cuboidal epithelium  
(b) Columnar epithelium  
(c) Pseudostratified epithelium  
(d) Stratified epithelium
- The cell junctions called tight, adhering and gap junctions are found in [NCERT; CBSE PMT 2009]  
(a) Muscular tissue (b) Connective tissue  
(c) Epithelial tissue (d) Neural tissue
- Note the following  
(A) It forms the lining of the cavities of alveoli of the lungs  
(B) It forms the lining of wet surfaces like buccal cavity and oesophagus  
(C) It occurs in the ducts of sweat glands  
(D) It forms the lining of salivary glands and sweat glands  
(E) It is a loose connective tissue  
Which of the above are associated with simple epithelial tissue [EAMCET 2009]  
(a) A and D (b) B and C  
(c) C and A (d) D and E
- Mammary glands are modified [BHU 2008]  
(a) Cutaneous glands (b) Sebaceous glands  
(c) Sweat glands (d) Scent glands
- In which one of the following preparations are you likely to come across cell junctions most frequently [CBSE PMT 2007]  
(a) Ciliated epithelium (b) Thrombocytes  
(c) Tendon (d) Hyaline cartilage
- The function of villi in the intestine is [NCERT; AIEEE Pharmacy 2003; CBSE PMT 2005; Odisha JEE 2010]  
(a) Absorption of food  
(b) Increase in the absorptive surface of food  
(c) Control of intestinal movement  
(d) Hinderance in the movement of food
- Reproductive cells (germinal epithelium) are made up of which of the following epithelial tissue  
(a) Cuboidal (b) Columnar  
(c) Squamous (d) Sensory
- Schneiderian membrane is found in  
(a) Nasal passage (b) Trachea  
(c) Bowman's capsule (d) Loop of Henle
- The ciliated epithelium in our body may be found in [CBSE PMT 1993; MP PMT 1997; RPMT 2005, 06]  
(a) Ureter (b) Trachea  
(c) Stomach (d) Uterine tube
- Cells of squamous epithelium are [MP PMT 1994]  
(a) Tall with elongated nuclei  
(b) Cube like  
(c) Flat and tile like  
(d) Columnar or cuboidal in shape
- The cells lining the blood vessels belong to the category of [NCERT; J & K CET 2008; CBSE PMT (Pre.) 2010; CBSE PMT (Malwa) 2011]  
(a) Columnar epithelium (b) Connective tissue  
(c) Smooth muscle tissue (d) Squamous epithelium
- Urethra, vagina and oesophagus have a common inner lining of [CMC Vellore 1993; MP PMT 2003; Odisha JEE 2005]  
(a) Squamous epithelium  
(b) Ciliated epithelium  
(c) Columnar epithelium  
(d) Stratified squamous epithelium
- Epithelial tissue performs the following functions [NCERT; KCET 1994; MP PMT 1995]  
(a) Protection, secretion, absorption, respiration  
(b) Protection, secretion, sensation, absorption  
(c) Protection, secretion, absorption, digestion  
(d) None of these
- Simple epithelium is [DPMT 1993]  
(a) One cell thick (b) Two cells thick  
(c) Two or three cells thick (d) All are correct
- The cellular layers in epidermis of skin consists of  
(a) Glandular cells  
(b) Columnar cells  
(c) A squamous stratified cornified epithelium  
(d) A complex stratified epithelium
- Ciliated epithelium in vertebrates is present in  
(a) Kidney and stomach  
(b) Buccal cavity and oviduct of frog  
(c) Stomach and urinary tubules  
(d) Lymph vessels
- The secretion of tears, milk, sweat and oil are functions of which of the following tissues [J & K CET 2012]  
(a) Epithelial (b) Nervous  
(c) Loose connective (d) Lymphoid
- Desmosomes are the feature of [CBSE PMT 1992; AFMC 1993, 99; KCET 2000; BHU 2001]  
(a) Epithelial tissue (b) Nervous tissue  
(c) Muscular tissue (d) None of these
- Nature of mammary gland is [MP PMT 2002]  
(a) Apocrine (b) Merocrine  
(c) Holocrine (d) None of these
- An example of merocrine gland is [MP PMT 2001]  
(a) Sebaceous gland (b) Pineal gland  
(c) Salivary gland (d) Mammary gland

24. Simple coiled tubular glands are found in [CPMT 1993]  
 (a) Dermis of skin (b) Kidney  
 (c) Liver (d) Spleen

25. See the following figures



Figure A and B indicate glands while Figure C indicates specific type of tissues. Identify A, B and C [NCERT]

	A	B	C
(a)	Unicellular gland	Goblet gland	Pseudostratified epithelium
(b)	Multicellular gland	Unicellular gland	Pseudostratified epithelium
(c)	Unicellular gland	Multicellular gland	Pseudostratified epithelium
(d)	Unicellular gland	Multicellular gland	Compound epithelium

26. In animals, gametes are derived from [Kerala PMT 2004]  
 (a) Epithelial tissue (b) Nervous tissue  
 (c) Occur singly (d) None of the above

27. Tissue which has power of division and regeneration throughout life

- (a) Epithelial tissue (b) Muscular tissue  
 (c) Connective tissue (d) Nervous tissue

28. The ciliated columnar epithelial cells in humans are known to occur in [NCERT; MP PMT 2000; AIEEE Pharmacy 2004; Kerala PMT 2007; CBSE PMT (Pre.) 2011; WB JEE 2011]

- (a) Fallopian tubes and urethra  
 (b) Eustachian tube and stomach lining  
 (c) Bronchioles and Fallopian tubes  
 (d) Bile duct and oesophagus

29. Stratified squamous epithelium is found in [AFMC 1995]

- (a) Trachea (b) Epidermis  
 (c) Mouth cavity (buccal) (d) Lining of blood vessels

30. Compound squamous epithelium is found in [BHU 1995]

- (a) Stomach (b) Intestine  
 (c) Trachea (d) Pharynx

31. Find out the wrongly matched pair [Kerala PMT 2007]

- (a) Squamous epithelium - Skin of frog  
 (b) Columnar epithelium - Peritoneum of body cavity  
 (c) Ciliated epithelium - Bronchioles  
 (d) Stratified cuboidal epithelium - Oesophagus  
 (e) Glandular epithelium - Salivary gland

32. The epithelium in the bronchioles is [MP PMT 1996, 2002]

- (a) Pseudostratified and columnar  
 (b) Squamous and sensory  
 (c) Pseudostratified and sensory  
 (d) Cuboidal and columnar

33. Which type of epithelium is found in oesophagus, buccal cavity, cornea, vagina and cervix [KCET 2007; Odisha JEE 2011]

- (a) Transitional epithelium  
 (b) Columnar epithelium  
 (c) Non-keratinized stratified epithelium  
 (d) Keratinized stratified epithelium

34. Match the following simple epithelial tissues in column I with their occurrence in column II and choose the correct combination from the options given

Column I	Column II
A. Squamous	1. Intestinal glands
B. Cuboidal	2. Trachea
C. Columnar	3. Ovary
D. Ciliated	4. Blood vessels
E. Pseudo stratified	5. Bronchioles

[DPMT 2004; Kerala PMT 2006]

- (a) A - 1, B - 2, C - 4, D - 3, E - 5  
 (b) A - 5, B - 4, C - 2, D - 1, E - 3  
 (c) A - 4, B - 5, C - 1, D - 2, E - 3  
 (d) A - 4, B - 3, C - 1, D - 2, E - 5  
 (e) A - 4, B - 3, C - 1, D - 5, E - 2

35. Which of the following is the characteristic of epithelial tissues [KCET 2001]

- (a) They are highly vascularised  
 (b) They never produce glands  
 (c) They have large intercellular spaces  
 (d) They have a rapid rate of cell division

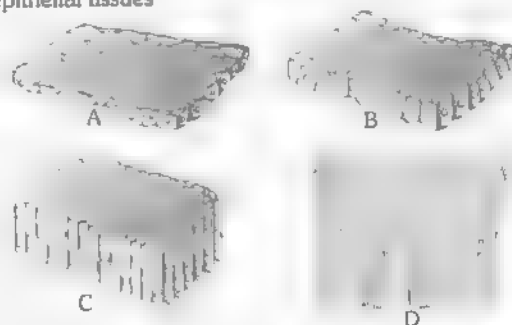
36. The type of epithelium found in conjunctiva of eye is [MP PMT 2001]

- (a) Stratified cuboidal (b) Stratified columnar  
 (c) Stratified squamous (d) Transitional epithelium

37. Outer layer of skin is made up of keratinised epithelium, this is because [RPMT 2001]

- (a) It is exposed thus subjected to wear and tear  
 (b) It covers the whole body  
 (c) It is thick  
 (d) It prevents the entry of pathogens

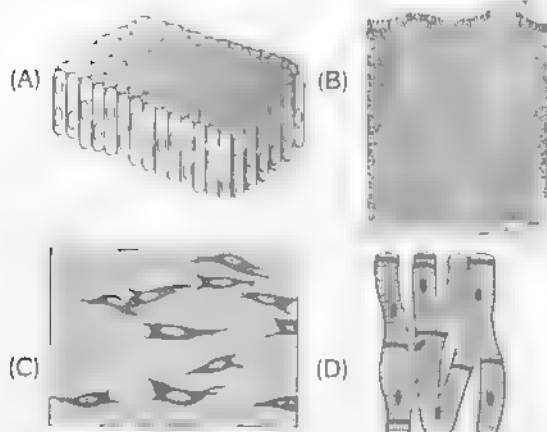
38. See the following figure and identify the following simple epithelial tissues [NCERT]



	A	B	C	D
(a)	Squamous	Cuboidal	Columnar	Pseudostratified columnar (ciliated)
(b)	Pseudostratified squamous	Cuboidal	Columnar	Ciliated columnar
(c)	Squamous	Cuboidal	Columnar	Ciliated columnar
(d)	Cuboidal	Squamous	Columnar	Ciliated columnar



39. The intestine and stomach in mammals are lined by [J & K CET 2002]  
 (a) Cuboidal epithelium (b) Columnar epithelium  
 (c) Squamous epithelium (d) Stratified epithelium
40. Pseudostratified columnar epithelium is found in [MP PMT 2003]  
 (a) Wall of cloaca (b) Male urethra  
 (c) Oviduct (d) Oesophagus
41. Epithelial tissues arise from [MP PMT 1996, 2002]  
 (a) Ectoderm (b) Endoderm  
 (c) Mesoderm (d) All of the above
42. The four sketches (A, B, C and D) given below, represent four different types of animal tissues. Which one of these is correctly identified in the options given, along with its correct location and function [NCERT; CBSE PMT (Mains) 2012]



		Tissue	Location	Function
(a)	(B)	Glandular epithelium	Intestine	Secretion
(b)	(C)	Collagen fibres	Cartilage	Attach skeletal muscles to bones
(c)	(D)	Smooth muscle tissue	Heart	Heart contraction
(d)	(A)	Columnar epithelium	Nephron	Secretion and absorption

### Connective tissue

1. Glisson's capsule is a delicate connective tissue capsule covering the [KCET 1994; MP PMT 2002]  
 Or  
 Glisson's capsule is found in [MP PMT 1998, 2009; CPMT 2001; Kerala PMT 2008]  
 (a) Spleen (b) Liver  
 (c) Kidney (d) Gall bladder
2. The type of connective tissue that is associated with the umbilical cord is [EAMCET 2009]  
 (a) Areolar connective tissue  
 (b) Jelly-like connective tissue  
 (c) Adipose connective tissue  
 (d) Reticular connective tissue

3. Which of the following cells of connective tissue secrete antibodies [CPMT 2005]  
 (a) Mast cells (b) Reticular cells  
 (c) Adipose cells (d) Plasma cells
4. The mast cells secrete the following substance [DPMT 1993; CBSE 1998, 2006; CPMT 1998, 2000, 03, 09; AFMC 2002; BHU 2003, 06; MP PMT 2007]  
 (a) Heparin (b) Histamine  
 (c) Serotonin (d) All of the above
5. Originating in bone marrow, circulating in blood for 1–2 days, migrating to connective tissue and forming macrophages is a characteristic of [AMU (Med.) 2010]  
 (a) Eosinophils (b) Basophils  
 (c) Monocytes (d) Lymphocytes
6. In allergic reaction which is secreted [Bihar CECE 2006; AIIMS 2009]  
 Or

The symptoms of an allergic reaction develop in response to [WB JEE 2016]

- (a) Histamine (b) Neutrophil  
 (c) Basophil (d) Acidophil
7. The areolar tissue connects [CBSE PMT 2006]  
 (a) Two bones  
 (b) Muscle and the bone  
 (c) Muscle and the fat tissue  
 (d) Muscles and their compound
8. Ligaments and tendons are [NCERT; MP PMT 1996; AFMC 1999, 2010; CPMT 2001, 03; BHU 2006]  
 (a) Connective tissue (b) Muscular tissue  
 (c) Fibrous connective tissue (d) Skeletal tissue
9. Collagen fibres of connective tissue are [NCERT; CPMT 1999; J & K CET 2012]  
 (a) White (b) Yellow  
 (c) Colourless (d) Red
10. Camel's hump is made up of [DPMT 1993; MHCET 2004]  
 (a) Skeletal tissue (b) Muscular tissue  
 (c) Cartilage (d) Adipose tissue
11. Study the figure I and II carefully and identify the structures A, B and C respectively which are related with specialized connective tissues [NCERT]

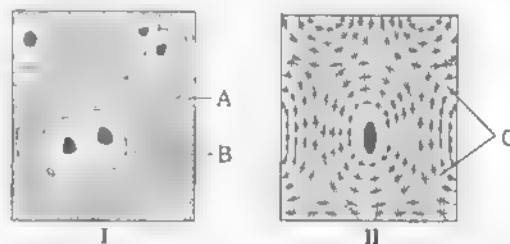


	Fig. I	Fig. II	A	B	C
(a)	Bone	Cartilage	Collagen fibres	Osteoblast	Lamella
(b)	Cartilage	Bone	Microtubule	Chondroclast	Lamella
(c)	Cartilage	Bone	Collagen	Chondroclast	Lamella
(d)	Cartilage	Bone	Collagen	Chondrocyte	Lamella

12. Whale is a warm-blooded animal which lives in cold sea. Which organ of its body makes it hot  
(a) Blubber (b) Pelage  
(c) Muscles (d) Blood vessels

13. Below the skin, the fat is in the form of

Or

Which of the following helps in maintaining body hot

- (a) Lipoproteins (b) Adipose tissue  
(c) Mucous layer (d) Lymphoid tissue
14. Which statement is incorrect [AMU (Med.) 2010]  
(a) Mast cells and basophils secrete histamine and heparin  
(b) Mast cells are long lived, basophils are short lived  
(c) Mast cells are smaller than basophils with a bilobed nucleus  
(d) Mast cells are relatively sessile, basophils are mobile
15. The types of fibres found in connective tissues are  
(a) Collagen fibres (b) Elastic fibres  
(c) Reticular fibres (d) All of the above
16. The intercellular substance found in connective tissue is  
(a) Fatty in nature  
(b) Muco-polysaccharide  
(c) Mainly protein in nature  
(d) All are correct
17. Given below is the diagrammatic sketch of a certain type of connective tissue. Identify the parts labelled A, B, C and D, and select the right option about them

[NCERT; CBSE PMT (Mains) 2012]



	Part-A	Part-B	Part-C	Part-D
(a)	Macro-phage	Fibroblast	Collagen fibres	Mast cells
(b)	Mast cell	Macro-phage	Fibroblast	Collagen, fibres
(c)	Macro-phage	Collagen fibres	Fibroblast	Mast cell
(d)	Mast cell	Collagen fibres	Fibroblast	Macro-phage

18. Most of the cells in areolar tissue are [NCERT; [CBSE PMT 1992; MP PMT 1996; Kerala PMT 2010]

- (a) Fibroblasts (b) Macrophages  
(c) Mast cells (d) All the above

19. Histiocyte is a connective tissue cell, the function of which is

- (a) Phagocytic (b) Secretion  
(c) Substance (d) Fibre production

20. Ligament is mainly made up of [MP PMT 2007]

- (a) Reticulin (b) Elastin  
(c) Myosin (d) Collagen

21. A localised inflammatory response appears at the site of infection causes redness, swelling, pain and heat due to certain chemical, they are [KCET 2007; J & K CET 2012]

- (a) Histamine and prostaglandins  
(b) Cerumen and mucus  
(c) Histamine and cerumen  
(d) Prostaglandins and cerumen

22. Thousand of year old Mummies are still in their condition as they were before due to non-destruction of [BHU 2005, 12]

- (a) Yellow elastin fibres (b) White elastin fibres  
(c) Collagen fibres (d) Veins

23. White adipose tissue contains [MP PMT 2003]

- (a) Multilocular fat cells (b) Bilocular fat cells  
(c) Unilocular fat cells (d) Alocular fat cells

24. The given figure is of adipose tissue, Identify marked alphabets



[NCERT]

	A	B	C
(a)	Fat storage area	Nucleus	Cell membrane
(b)	Nucleus	Fat	Cell membrane
(c)	Cytoplasm	Fat	Cell membrane
(d)	Vacuole	Fat	Cell membrane

25. Debove's membrane is a layer of [BHU 2004]

- (a) Muscular tissue (b) Epithelial tissue  
(c) Connective tissue (d) All of these

26. Which among the following is not characteristic of yellow fibres of connective tissue [Kerala PMT 2004]

- (a) Contain elastin  
(b) Fewer in number  
(c) Straight and branched  
(d) Provide toughness and strength  
(e) Occur singly

27. Which one of the following is not a fibrillar protein

[Kerala CET 2003]

- (a) Elastin (b) Collagen  
(c) Myosin (d) Albumin

28. Vitreous humor is

[BVP 2003]

- (a) Mucoïd connective tissue (b) Solid crystalline  
(c) Watery fluid (d) All of these

29. Which of these if not found in connective tissue

[MP PMT 2010]

- (a) Hyaluronic acid (b) Basement membrane  
(c) Collagen fibres (d) Fluid

30. The ground substance of connective tissue is basically composed of [MP PMT 1997]

- (a) Mucopolysaccharides (b) Lipids  
(c) Monosaccharides (d) Phospholipids

31. Adipocytes are mainly found in [NCERT; MP PMT 1997]  
 (a) Bones (b) Cartilages  
 (c) Connective tissue (d) Nerves

32. Arbor vitae is composed of [AIIMS 1998]  
 (a) Grey matter (b) Neuroglial cells  
 (c) White matter (d) All of these

33. Ligament is [CBSE PMT 1999; BHU 2000]  
 (a) Modified white fibrous tissue  
 (b) Modified yellow elastic fibrous tissue  
 (c) Inelastic white fibrous tissue  
 (d) None of these

34. Choose the correctly matched pair [CPMT 1999; JIPMER 2001; CBSE PMT 2014]  
 (a) Areolar tissue – Loose connective tissue  
 (b) Cartilage – Loose connective tissue  
 (c) Tendon – Specialized connective tissue  
 (d) Adipose tissue – Dense connective tissue

35. Which of the following is not a connective tissue [CPMT 2010]  
 (a) Blood (b) Lymph  
 (c) Nerve (d) Bone

36. Which of the following cells is phagocytic in nature [AFMC 2000; Odisha JEE 2011]  
 (a) Mast cell (b) Podocytes  
 (c) Macrophages (d) Fibroblast cells

37. Connective tissue is [Odisha JEE 2002]  
 (a) Ectodermal in origin with intercellular spaces  
 (b) Mesodermal in origin without intercellular spaces  
 (c) Ectodermal in origin without intercellular spaces  
 (d) Mesodermal in origin with intercellular spaces

38. Mast cells are found in [NCERT; MP PMT 1997]  
 (a) Connective tissue (b) Muscular tissue  
 (c) Nervous tissue (d) Blood

39. Collagen is [CBSE PMT 2002]  
 (a) Lipid (b) Carbohydrate  
 (c) Globular protein (d) Fibrous protein





40. Which one of the following contains the largest quantity of extracellular material [NCERT; CBSE PMT 2003]  
 (a) Myelinated nerve fibres (b) Striated muscle  
 (c) Areolar tissue (d) Stratified epithelium

41. Fibroblasts, macrophages and mast cells are seen in [Kerala PMT 2011]  
 (a) Epithelial tissue (b) Connective tissue  
 (c) Skeletal muscle tissue (d) Smooth muscle tissue  
 (e) Neural tissue

42. Which of the following tissues is most abundant and forms most of the body parts [NCERT; Odisha JEE 2011]  
 (a) Nervous tissue (b) Muscle tissue  
 (c) Connective tissue (d) Epithelial tissue

43. The falciform ligament in man connects [NCERT; AMU (Med.) 2012]  
 (a) Liver with diaphragm (b) Lungs with diaphragm  
 (c) Stomach with diaphragm (d) Liver with stomach

44. Select the option having all three correct characteristics [AIIMS 2012]

	Structure	Percentage	Function
(a)		0.3 – 0.5	Phagocytic
(b)		0.5 – 1	Secrete histamine and serotonin
(c)		30 – 40	Defence against parasites
(d)		30 – 40	Allergic reactions

45. Identify the following figure – A and B respectively [NCERT]

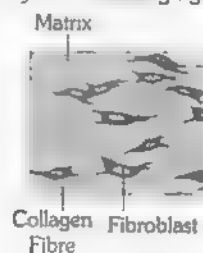


Fig. A

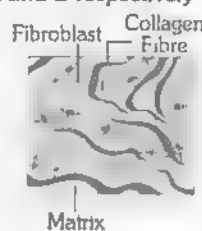


Fig. B

- (a) Connective tissue proper, specialized connective tissue  
 (b) Adipose tissue, specialized connective tissue  
 (c) Dense irregular connective tissue, dense regular connective tissue  
 (d) Dense regular connective tissue, dense irregular connective tissue

### Skeletal tissue

1. Haversian system is a diagnostic feature of [KCET 1994; MP PMT 2001; DPMT 2003]  
 (a) Avian bones (b) All animals  
 (c) Mammalian bones only (d) Reptilian bones
2. Which of the following tissue is more elastic  
 (a) Bone (b) Cartilage  
 (c) Both are equally elastic (d) Both are not elastic
3. Haversian system are found in the [BVP 2002]  
 (a) Pigeon (b) Panther  
 (c) Pipe fish (d) Python
4. Which of the following tissue is called as "homeostatic reservoir"  
 (a) Cartilage (b) Bone  
 (c) Calcified cartilage (d) All the above
5. During an injury, nasal septum gets damaged and for its recovery which cartilage is perfused [CBSE PMT 2001]

Or

- Which of the following is a transparent tissue [CPMT 2001; BHU 2006; MP PMT 2012]  
 (a) Hyaline cartilage (b) Elastic cartilage  
 (c) Calcified cartilage (d) Fibro cartilage

6. Role of bone-marrow in mammals is [MP PMT 1995]  
 (a) To assist kidneys  
 (b) To act as haemopoietic tissue  
 (c) To assist liver  
 (d) To control blood pressure
7. Pubis in the frog's pelvic girdle is actually a [BVP 2003]  
 (a) Calcified cartilage (b) Cartilaginous bone  
 (c) Membrane bone (d) None of these
8. Which among the following is the strongest cartilage [CPMT 2000, 03; BHU 2003]  
 (a) Hyaline cartilage (b) Elastic cartilage  
 (c) White fibro cartilage (d) Violet fibro cartilage
9. Protein present in cartilage is [CBSE PMT 1997]  
 Or  
 The matrix of hyaline cartilage contains [CPMT 1998]  
 Or  
 The skeletal tissue consists of organic matrix called as [CBSE PMT 1993]  
 (a) Chondrin (b) Osein  
 (c) Cartilagin (d) Ossein
10. The supportive skeletal structures in the human external ears and in the nose tip are examples of [CBSE PMT (Mains) 2012]  
 (a) Ligament (b) Areolar tissue  
 (c) Bone (d) Cartilage
11. Covering around bone is called [RPMT 2005]  
 (a) Perichondrion (b) Periosteum  
 (c) Epiosteum (d) Endosteum
12. Haversian canals of long bones have  
 (a) One vein and one artery  
 (b) One nerve and one lymphatic  
 (c) Some bone cells, fat and areolar tissue  
 (d) All the above
13. Cartilage is formed by [NCERT; MP PMT 1993, 94; Manipal 1995]  
 (a) Osteoblast (b) Fibroblast  
 (c) Chondrocyte (d) Submucosa
14. In mammals Haversian canals are connected with each other by transverse canals, which are called [MP PMT 2001, 03; KCET 2004; AFMC 2008]  
 (a) Semicircular canals (b) Volkman's canals  
 (c) Inguinal canals (d) Bidder's canals
15. Major constituent of bone is [NCERT; RPMT 1999; WB JEE 2012; AMU (Med.) 2012]  
 (a) Calcium phosphate (b) Magnesium phosphate  
 (c) Calcium carbonate (d) Sodium chloride
16. The tendon are formed of [DPMT 1999; CBSE PMT 1999; JIPMER 2001; CPMT 2003]  
 (a) White fibrous tissue (connective)  
 (b) Yellow fibrous tissue (connective)  
 (c) Areolar tissue  
 (d) Adipose tissue
17. Intervertebral disc is made up of [AIIMS 1993; MP PMT 2003]  
 (a) Elastic cartilage (b) Fibrous cartilage  
 (c) Calcified cartilage (d) Hyaline cartilage
18. Red marrows of the bone produce [AIIMS 1993]  
 (a) Lymphocytes (b) Eosinophils  
 (c) Plasma (d) RBC
19. The connective tissue of the vertebrate body is built up from fibres of the protein collagen, embedded in a polysaccharide matrix to form [CBSE PMT 1993]  
 (a) Cartilage (b) Blood vessel  
 (c) Heart (d) Lung
20. In the matrix lies the bone cells, called [CBSE PMT 1993]  
 Or  
 Cells that maintain marrow cells are called [AFMC 2009]  
 (a) Chondroclasts (b) Osteoclasts  
 (c) Osteoblasts (d) Osteocytes
21. A femur is kept in dilute HCl for three days, it becomes [CBSE PMT 1993]  
 (a) Brittle (b) Soft and elastic  
 (c) Remains as it is (d) Harder
22. A tissue similar to ligament but stretchable is called  
 (a) Tendon (b) Raphe  
 (c) Both (a) and (b) (d) None of these
23. Bone-forming cells are known as [NCERT; KCET 1998; PET (Pharmacy) 2013]  
 (a) Chondroclasts (b) Osteoblasts  
 (c) Chondroblasts (d) Osteoclasts
24. A polysaccharide constituent found in the matrix of cartilage is [NCERT; AFMC 2012]  
 (a) Ossein (b) Collagen  
 (c) Chondroitin (d) Hyaline

### Vascular tissue

1. Which is not the cellular element of blood [Odisha JEE 2008]  
 (a) T-cell (b) B-cell  
 (c) Plasma (d) Monocyte
2. Average life span of human RBC is [NCERT; MP PMT 2001, 10; CPMT 2003; AFMC 2005; Odisha JEE 2005; BHU 2008]  
 (a) 100 days (b) 90 days  
 (c) 120 days (d) None
3. When the count of WBC falls below the optimum number in blood, it is called [Odisha JEE 2005]  
 (a) Leukopenia (b) Leukemia  
 (c) Anaemia (d) All of the above
4. Globulins contained in human blood plasma are primarily involved in [CBSE PMT 2009]  
 (a) Defence mechanisms of body  
 (b) Osmotic balance of body fluids  
 (c) Oxygen transport in the blood  
 (d) Clotting of blood
5. The most active phagocytic white blood cells are [CBSE PMT 2008]  
 (a) Eosinophils and lymphocytes  
 (b) Neutrophils and monocytes  
 (c) Neutrophils and eosinophils  
 (d) Lymphocytes and macrophages

6. Natural killer lymphocytes are an example for [KCET 2015]  
(a) Physical barrier (b) Cytokine barrier  
(c) Cellular barrier (d) Physiological barrier
7. Both RBC and WBC are formed in the [CPMT 2003; Odisha JEE 2009]  
(a) Thymus (b) Adrenal  
(c) Thyroid (d) Bone marrow
8. Erythrocytes in camel are  
(a) Oval and non-nucleated  
(b) Oval and nucleated  
(c) Circular, biconcave and non-nucleated  
(d) Circular, biconvex and nucleated
9. Shape of the nucleus of WBC is usually  
(a) Spherical (b) Irregular  
(c) Oval (d) Spindle shaped
10. Lymph differs from blood in having  
(a) No W.B.C. (b) No protein  
(c) Much more of water (d) No R.B.C.
11. A matured mammalian (RBC) is unusual because [NCERT; Odisha JEE 2009]  
(a) It exhibits diapedesis (b) It is colourless  
(c) It has no nucleus (d) It can change its shape
12. Largest single mass of lymphatic tissue in the body is [DUMET 2009]  
(a) Lung (b) Spleen  
(c) Liver (d) Kidney
13. Note the following:  
(A) Monocytes (B) Trophocytes  
(C) Lymphocytes (D) Mycetocytes  
(E) Leucocytes (F) Oenocytes  
Which of above are fat cells in *Periplaneta* [EAMCET 2009]  
(a) A, C, E and H (b) B, D, F and G  
(c) C, E, F and G (d) A, C, E and F
14. In the clotting mechanism pathway thrombin activates factors [AMU (Med.) 2010]  
(a) XI, VIII, V (b) XI, IX, X  
(c) VIII, X, V (d) IX, VIII, X
15. If kept in 0.8% NaCl, R.B.Cs will  
(a) Shrink (b) Remain same  
(c) Burst (d) None of these
16. pH of human blood is [MP PMT 1999]  
(a) 7.4 (b) 6.2  
(c) 9.0 (d) 10.00
17. The largest RBC's have been seen in [KCET 2007]  
(a) Elephant (b) Whale  
(c) Amphibia (d) Man
18. Blood clotting can be prevented in a test tube by adding a little  
(a) Sodium oxalate (b) Sodium chloride  
(c) Sodium hydroxide (d) Ammonium chloride
19. A siderocyte is a RBC containing [AMU (Med.) 2009]  
(a) Pappenhiemer bodies (b) Russel bodies  
(c) Herring's bodies (d) Schuffner's dots
20. What product of the immune system attaches to bacteria, making them easier to be eaten by white blood cells [J & K CET 2012]  
(a) Antigen (b) Haemoglobin  
(c) Antibody (d) MHC I molecule
21. Which of the following cells are associated with immune system of body [MP PMT 2003]  
(a) Neutrophils (b) Macrophages  
(c) Lymphocytes (d) All of these
22. Usually chordates have red blood containing red blood corpuscles. The blood is red due to the presence of the following pigment [DPMT 1993; AFMC 1993]  
(a) Myoglobin (b) Anthocyanin  
(c)  $\beta$  anthocyanin (d) Haemoglobin
23. The chemical which causes damage of WBC, bone marrow, spleen, lymph nodes and lungs is [AIIMS 1993]  
(a) Iodine -131 (b) Calcium  
(c) Strontium -90 (d) Iodine -127
24. Neutrophils promote adhesion of neutrophils to endothelium, attract other neutrophils, monocytes and eosinophils and dilate capillaries by secreting [AMU (Med.) 2009]  
(a) Cytokines (b) Leucotrienes  
(c) Lymphokines (d) Monokines
25. Mineral present in red pigment of vertebrate blood is  
(a) Magnesium (b) Iron  
(c) Copper (d) Calcium
26. Blood is formed of [NCERT; MP PMT 1994]  
(a) Plasma and bone marrow cells  
(b) Plasma and white and red blood cells  
(c) Plasma and white blood cells  
(d) Plasma and red blood cells
27. During sleeping the rate of RBC formation  
(a) Increases (b) Decreases  
(c) Remains constant (d) None of the above
28. In the extrinsic clotting pathway the active factor VII activates factors [AMU (Med.) 2009]  
(a) X and XI (b) IX and XI  
(c) IX and X (d) XI and XII
29. Blood is a kind of [Bihar CECE 2006; MP PMT 2009; Odisha JEE 2012]  
(a) Areolar tissue (b) Connective tissue  
(c) Fluid connective tissue (d) Reticular connective tissue
30. Match the following
- | Types of leucocytes | Function                              |
|---------------------|---------------------------------------|
| A. Neutrophils      | 1. Heparin and histamine secretion    |
| B. Basophils        | 2. Antibodies formation               |
| C. Acidophils       | 3. Scavenger                          |
| D. Monocytes        | 4. Phagocytes                         |
| E. Lymphocytes      | 5. Antiallergic and healing of wounds |
- The correct pairing sequence is [NCERT; BHU 2002, 05; Kerala PMT 2006, 08, 2010, 11; CBSE PMT 2008; Odisha JEE 2011]  
(a) 3, 1, 5, 4, 2 (b) 1, 4, 5, 3, 2  
(c) 3, 2, 1, 4, 5 (d) 2, 3, 1, 4, 5

31. Match the following

Disease	Cause
A. Diabetes	1. Rise in WBC count
B. Uraemia	2. Deficiency of vitamin B <sub>12</sub>
C. Anaemia	3. Rise in RBC count
D. Polycythemia	4. Fall of WBC count
E. Pernicious or Megaloblastic anaemia	5. Fall in RBC count
F. Leukemia	6. Increase in blood sugar level
G. Thrombocytopenia	7. Urea is in excess in blood
H. Leucopenia	8. Pathological increase in WBC
I. Leucocytosis	9. Decrease in the number of platelets

The correct matching sequence is

- (a) 1, 3, 4, 2, 5, 6, 7, 9, 8    (b) 6, 7, 5, 3, 2, 8, 9, 4, 1  
(c) 6, 7, 3, 5, 8, 2, 9, 1, 4    (d) 7, 6, 5, 3, 2, 9, 8, 4, 1

32. The average diameter of red blood corpuscles of man is

[WB JEE 2009]

- (a) 7.2  $\mu\text{m}$                       (b) 8.1  $\mu\text{m}$   
(c) 9.2  $\mu\text{m}$                       (d) 10.3  $\mu\text{m}$

33. Which one of the following leucocytes transforms into macrophages

[WB JEE 2009]

- (a) Eosinophil                      (b) Basophil  
(c) Monocyte                      (d) Lymphocyte

34. Reticulocytes may also be called

- (a) Blood platelets                      (b) Immature erythrocytes  
(c) Lymphocytes                      (d) WBCs

35. Phagocytosis was first of all seen by

[BHU 1995]

- (a) Huxley                      (b) Haeckel  
(c) Metchnikoff                      (d) Strasburger

36. Highest content of iron is found in

[RPMT 1995]

- (a) WBC                      (b) Bone cells  
(c) RBC                      (d) Protein

37. Which is the correct sequence of arrangement of types of WBC in decreasing order in terms of number per  $\text{mm}^3$  of human blood

[WB JEE 2009]

- (a) Eosinophils > basophils > neutrophils  
(b) Basophils > eosinophils > neutrophils  
(c) Neutrophils > eosinophils > basophils  
(d) Eosinophils > neutrophils > basophils

38. These WBCs makes maximum count amongst leucocyte

[GUJCET 2007]

- (a) Neutrophils                      (b) Eosinophils  
(c) Basophils                      (d) Lymphocytes

39. The largest corpuscles in mammalian blood are

[MP PMT 1997]

- (a) Basophils                      (b) Erythrocytes  
(c) Monocytes                      (d) Lymphocytes

40. Blood does not clot inside the blood vessels due to the presence of

[DPMT 1993; JIPMER 1993;  
AIIMS 1993, 99; CPMT 1994; MP PMT 1997;  
BHU 2001; AFMC 2003; WB JEE 2010]

- (a) Heparin                      (b) Fibrinogen  
(c) Vitamin K                      (d) Thrombin

41. Antibody is produced by

[NCERT; BHU 2003;

AIEEE Pharmacy 2003; AFMC 2009]

- (a) B-Lymphocyte                      (b) Heparin  
(c) T-Lymphocyte                      (d) Both (a) and (b)

42.  $\gamma$ -globulins are synthesised inside

[CPMT 1999]

- (a) Liver  
(b) Bone marrow  
(c) Lymph and lymphoid tissue  
(d) Kidney

43. Which of the following is agranulocyte

[CBSE PMT 1997]

- (a) Lymphocyte                      (b) Eosinophil  
(c) Basophil                      (d) Neutrophil

44. The life span of human WBC is approximately

[CBSE PMT 1997]

- (a) Less than 10 days                      (b) Between 20 to 30 days  
(c) Between 2 to 3 months                      (d) More than 4 months

45. Which of the following is not a granulocyte

[NCERT; BHU 2000; CPMT 2010]

- (a) Basophils                      (b) Monocytes  
(c) Acidophils                      (d) Neutrophils

46. In haemoglobin which amino acid acts as blood buffer

[DPMT 2007]

- (a) Histidine                      (b) Glutamine  
(c) Aspartic acid                      (d) Lysine

47. According to Best and Taylor's theory, which of the following does not play any role in blood clotting

[KCET 2012]

- (a) Prothrombin                      (b) Fibrinogen  
(c) Platelets                      (d) Calcium ions

48. The chief difference between RBCs of Human and Frog

[NCERT; BVP 2002]

- (a) Only human RBCs have haemoglobin  
(b) Human RBCs have more nuclei  
(c) Human RBCs are without nucleus  
(d) Frog RBCs are without nucleus

49. Which of the following is enucleate

[NCERT; Kerala CET 2002]

- (a) Squamous epithelial cell  
(b) Mature human erythrocyte  
(c) Mature frog erythrocyte  
(d) Human osteocyte

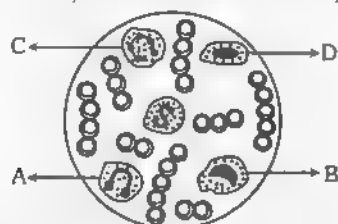
50. Helper T – Cells : Lymphokines as

Killer T – Cells : \_\_\_\_\_

[MHCET 2015]

- (a) Interferons                      (b) Lysozymes  
(c) Perforins                      (d) Prostaglandins

51. Study the diagram given below and identify the cells labelled as A, B, C and D, and choose the correct option



[KCET 2012]

- (a) A = Eosinophil B = Erythrocyte, C = Neutrophil and D = Basophil  
 (b) A = Eosinophil, B = Lymphocyte, C = Neutrophil and D = Monocyte  
 (c) A = Erythrocyte, B = Basophil, C = Neutrophil and D = Lymphocyte  
 (d) A = Eosinophil, B = Monocyte, C = Neutrophil and D = Lymphocyte
52. Which of the following is not phagocytic in nature [DPMT 2007; WB JEE 2011]  
 (a) Monocyte (b) Lymphocyte  
 (c) Mast cell (d) Neutrophil
53. Which of the following work as phagocytes [AFMC 2003]  
 (a) WBCs (b) RBCs  
 (c) Enzymes (d) Hormones
54. Serum is [Odisha JEE 2004]  
 (a) Blood without fibrinogen  
 (b) Lymph without corpuscles  
 (c) Blood without corpuscles and fibrinogen  
 (d) Lymph
55. Which is correct [Odisha JEE 2004]  
 (a) Blood has WBC and lymph has RBC  
 (b) Blood has WBC, RBC and lymph nothing  
 (c) Blood has RBC, WBC and lymph has WBC  
 (d) Lymph has WBC, RBC and blood has RBC
56. Which of the following does not play a role in blood coagulation [CPMT 2004]  
 (a) Vitamin K (b) Vitamin D  
 (c) Calcium ions (d) Fibrinogen
57. Which is not the function of lymph [MHCET 2015]  
 (a) Transport R B C.s  
 (b) Drain excess tissue fluid  
 (c) Transport lymphocyte and antibodies  
 (d) Transport absorbed fat
58. Hematology is the study of [BVP 2004]  
 (a) Bone (b) Blood  
 (c) Cartilage (d) Nerves
59. Antiserum contains [MH CET 2002; MP PMT 2012]  
 (a) Antigens (b) Antibodies  
 (c) Leucocytes (d) Heptaus
60. G-6-P dehydrogenase deficiency is associated with haemolysis of [CBSE PMT 2005]  
 (a) Lymphocytes (b) RBCs  
 (c) Platelets (d) Leucocytes
61. Which of the following substances, if introduced into the blood stream, cause coagulation of blood at the site of its introduction [CBSE PMT 2005]  
 (a) Fibrinogen (b) Prothrombin  
 (c) Heparin (d) Thromboplastin

62. Which are the phagocytic cells from given diagram [MHCET 2015]



- (a) I and V (b) I and III  
 (c) I and IV (d) I and II
63. The process of formation of RBCs is called [AFMC 2009]  
 (a) Poikegenesis (b) Erythropoiesis  
 (c) Leucogenesis (d) None of these
64. Which of the following is not the main function of lymph glands [CBSE PMT 1998; AFMC 1999]  
 (a) Forming WBC (b) Forming antibodies  
 (c) Forming RBC (d) Destroying bacteria
65. The process of formation of blood corpuscles is called [AFMC 2005]  
 (a) Haemopoiesis (b) Heamolysis  
 (c) Heamozoin (d) None of these
66. Mark the odd one [AFMC 2005]  
 (a) Monocytes (b) Lymphocyte  
 (c) Neutrophils (d) Erythrocytes
67. A drop of each of the following, is placed separately on four slides. Which of them will not coagulate [CBSE PMT 2007]  
 (a) Blood plasma  
 (b) Blood serum  
 (c) Sample from the thoracic duct of lymphatic system  
 (d) Whole blood from pulmonary vein
68. If haemoglobin (Hb) of a normal individual and a sickle-cell patient are run in electrophoretic field, they will show [AMU (Med.) 2012]  
 (a) Same mobilities  
 (b) Different mobilities  
 (c) Hb of patient will not move at all  
 (d) Hbs are immobile
69. Which of the following is a type of white blood cell [Odisha JEE 2012]  
 (a) Reticulocyte (b) Lymphocyte  
 (c) Erythrocyte (d) Osteocyte
70. Which of the following is absent in blood serum [Odisha JEE 2012]  
 (a) Antigens (b) Fibrinogen  
 (c) Hormones (d) Antibodies
71. Irregular nuclei is present in [MP PMT 2007]  
 Or  
 Which white blood cell releases chemical to inhibit blood clotting [WB JEE 2016]  
 (a) Neutrophils (b) Basophils  
 (c) Eosinophils (d) Monocytes
72. Which option is correct for the formation of 'Intrinsic factor - X activator complex for blood coagulation' [GUJCET 2014]  
 (a) Inactivated Christmas factor + AHG + phospholipids +  $\text{Ca}^{2+}$   
 (b) Activated Christmas factor + AHG + phospholipids +  $\text{Ca}^{2+}$   
 (c) Convertin + AHG +  $\text{Ca}^{2+}$  + FSF  
 (d) Phospholipid + protein complex + Proconvertin

73. Match the following

- |               |                          |
|---------------|--------------------------|
| A. Neutrophil | 1. Single large nucleus  |
| B. Eosinophil | 2. 2 to 3 lobed nucleus  |
| C. Basophil   | 3. Kidney shaped nucleus |
| D. Lymphocyte | 4. 2 to 7 lobed nucleus  |
| E. Monocyte   | 5. Bilobed nucleus       |

[Kerala PMT 2006]

- (a) (A) – (4), (B) – (1), (C) – (3), (D) – (5), (E) – (2)  
 (b) (A) – (2), (B) – (5), (C) – (1), (D) – (4), (E) – (3)  
 (c) (A) – (4), (B) – (5), (C) – (2), (D) – (1), (E) – (3)  
 (d) (A) – (2), (B) – (4), (C) – (5), (D) – (3), (E) – (1)  
 (e) (A) – (1), (B) – (4), (C) – (3), (D) – (2), (E) – (5)

74. Innate immunity is provided by

[Bihar CECE 2006; J &amp; K CET 2008]

- |                 |              |
|-----------------|--------------|
| (a) Neutrophils | (b) T- cells |
| (c) B- cells    | (d) Antibody |

75. Amount of oxygen supplied by 100ml arterial blood while passing through the tissues is [WB JEE 2012]

- |                |              |
|----------------|--------------|
| (a) 0.4-0.6 ml | (b) 4-6 ml   |
| (c) 14-15 ml   | (d) 19-20 ml |

76. People who have migrated from the plains to an area adjoining Rohtang Pass about six months back

[NCERT; CBSE PMT (Pre.) 2012]

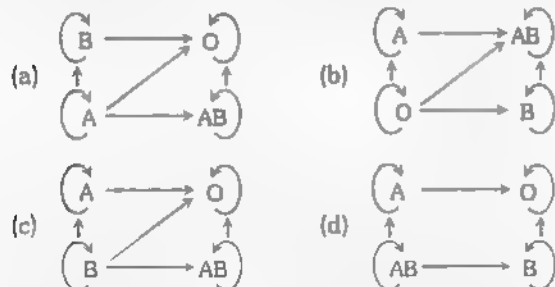
- (a) Have more RBCs and their haemoglobin has a lower binding affinity to  $O_2$   
 (b) Are not physically fit to play games like football  
 (c) Suffer from altitude sickness with symptoms like nausea fatigue etc  
 (d) Have the usual RBC count but their haemoglobin has very high binding affinity to  $O_2$

77. Compared to those of humans, the erythrocytes in frog are

[NCERT; CBSE PMT (Pre.) 2012]

- (a) Without nucleus but with haemoglobin  
 (b) Nucleated and with haemoglobin  
 (c) Very much smaller and fewer  
 (d) Nucleated and without haemoglobin

78. See the following representations and identify the correct blood groups and donor compatibility [NCERT]



79. Heparin is secreted by

[MH CET 2001; WB JEE 2010]

- |                 |                 |
|-----------------|-----------------|
| (a) Blood cells | (b) Liver cells |
| (c) Kidney      | (d) Nerve cell  |

80. If pH of blood is artificially changed to 8, what is most likely to happen [MP PMT 1992]

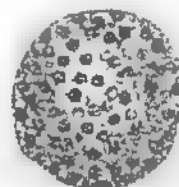
- (a) The tissues will not get oxygen as oxyhaemoglobin will not dissociate into oxygen and haemoglobin  
 (b) The carbon dioxide will not be released from carbonic acid and carbonates  
 (c) The carbonic anhydrase will be completely inhibited  
 (d) It will generate carbon monoxide and the animal will die of carbon monoxide poisoning

81. Erythropoiesis may be stimulated by the deficiency of

[AIIMS 1992]

- |             |                       |
|-------------|-----------------------|
| (a) Iron    | (b) Oxygen            |
| (c) Protein | (d) None of the above |

82. The figure shows a human blood cell. Identify it and give its characteristics



[NEET (Karnataka) 2013]

	Blood cell	Characteristics
(a)	Basophil	Secrete serotonin, inflammatory response
(b)	B-lymphocyte	Form about 20% of blood cells involved in immune response
(c)	Neutrophil	Most abundant blood cell, phagocytic
(d)	Monocyte	Life span 3 days, produce antibodies

83. Blood cells that increase in number during allergic conditions like asthma are [AIIMS 2010]

- |                 |                 |
|-----------------|-----------------|
| (a) Neutrophils | (b) Basophils   |
| (c) Eosinophils | (d) Lymphocytes |

84. The ratio of RBC to WBC in man is

- |             |              |
|-------------|--------------|
| (a) 6 : 1   | (b) 60 : 1   |
| (c) 600 : 1 | (d) 6000 : 1 |

85. Which of the following cells are round and biconcave in shape [Kerala PMT 2011]

- |                               |                     |
|-------------------------------|---------------------|
| (a) White blood cells         | (b) Red blood cells |
| (c) Columnar epithelial cells | (d) Nerve cells     |
| (e) Mesophyll cells           |                     |

86. Which one is correct [KCET 2007; AIPMT (Cancelled) 2015]

- (a) Blood = plasma + RBC + WBC + blood platelets  
 (b) Plasma = blood - lymphocytes  
 (c) Neuron = cyton + dendrite + axon + synapse  
 (d) Lymph = plasma + RBC + WBC

87. The sample of a healthy human blood is

- |              |                   |
|--------------|-------------------|
| (a) Alkaline | (b) Acidic        |
| (c) Neutral  | (d) None of these |

88. The iron free compound of haemoglobin is

- |               |                |
|---------------|----------------|
| (a) Globin    | (b) Haematin   |
| (c) Bilirubin | (d) Haemotoxin |



- 9. Haemoglobin contains  
(a) 70% globin + 30% haematin  
(b) 80% globin + 20% haematin  
(c) 95% globin + 05% haematin  
(d) 90% globin + 10% haematin
90. The process of blood clot formation within the circulatory system is [CBSE PMT 1993]  
(a) Thrombosis (b) Thrombocytes  
(c) Thrombin (d) Thrombocytopenia
91. If an experiment, animal is made anaemic, production of which hormone will be stepped up [AIIMS 1993]  
(a) Erythrocytin (b) Erythroblastin  
(c) Erythropoietin (d) Enkephalin
92. Lead concentration in blood is considered alarming if it is [CBSE PMT 2004; CPMT 2005]  
(a) 20  $\mu\text{g}/100\text{ ml}$  (b) 30  $\mu\text{g}/100\text{ ml}$   
(c) 10  $\mu\text{g}/100\text{ ml}$  (d) 4-6  $\mu\text{g}/100\text{ ml}$
93. Mature erythrocytes cannot utilize glucose because they lack [DUMET 2010]  
(a) Golgi complex (b) Enzymes  
(c) Mitochondria (d) Nucleus
94. The medium of plasma is  
(a) Acidic (b) Basic  
(c) Neutral (d) None of these
95. The pH of the blood is maintained balancing the ratio of  
(a) Lactic acid and pyruvic acid  
(b)  $\text{NaHCO}_3$  and  $\text{H}_2\text{CO}_3$   
(c)  $\text{CO}_2$  and  $\text{H}_2\text{O}$   
(d) Pyruvic acid and  $\text{H}_2\text{CO}_3$
96. What percent of total blood coming out of heart, goes to kidney [CPMT 1996]  
(a) 25% (b) 50%  
(c) 75% (d) 40%
97. The haemoglobin content per 100 ml of blood of a normal healthy human adult is [NCERT; CBSE PMT (Mains) 2010]  
(a) 5 to 11 gms (b) 25 to 30.0 gms  
(c) 17 to 20 gms (d) 12 to 16.0 gms
98. A yellow substance oozing out from wound has  
(a) Lymph + RBC + WBC  
(b) Lymph + RBC + dead bacteria  
(c) Lymph + WBC + dead bacteria  
(d) Lymph + dead leucocytes
99. WBC is called true cell because of [Odisha JEE 2011]  
(a) Presence of nucleus (b) Phagocytosis  
(c) Polymorphism (d) None of these
100. The main function of the white blood cell in the human intestine system is to [AIIMS 2010]  
(a) Combat and destroy antigenic particles  
(b) Produce antigens to combat antibodies  
(c) Carry oxygen around the body  
(d) Transport antigens to B memory cells in the lymph nodes
101. A chemical that prevents blood clotting is most useful in the treatment of  
(a) Leukemia (b) Anaemia  
(c) Coronary thrombosis (d) Haemophilia
102. Which one of the following substances in the blood in man imparts the oxygen carrying capacity to it  
(a) Haemocyanin  
(b) Haemoglobin  
(c) Haemerythrin or haemoerythrin  
(d) Sodium ions
103. Oxygen is transported by [MP PMT 1994, 95]  
(a) Blood plasma (b) RBCs  
(c) Leucocytes (d) Thrombocytes
104. Which one of the following in blood absorbs oxygen [MP PMT 1994]  
(a) WBCs (b) Plasma  
(c) RBCs (d) Platelets
105. In mammalian RBC, the percentage of haemoglobin is [CPMT 1996; MP PMT 2003]  
(a) 40% of biomass (b) 34% of biomass  
(c) 90% of biomass (d) 50% of biomass
106. Persons living at high altitude will have [AFMC 1995]  
(a) Increased alveolar capacity  
(b) Increased number of erythrocytes  
(c) Haemoglobin curve shifts towards right  
(d) All of the above
107. Red cell count is carried out by [WB JEE 2010]  
(a) Haemocytometer (b) Haemoglobinometer  
(c) Sphygmomanometer (d) Electrocardiogram
108. To prevent coagulation blood stored in blood bank contains a small amount of  
(a) Calcium sulphate  
(b) Prothrombin  
(c) Potassium or sodium citrate  
(d) None of these
109. Which of the following blood cells help in blood coagulation [AFMC 2010; Odisha JEE 2010]  
(a) RBCs (b) Lymphocytes  
(c) Thrombocytes (d) Basophils
110. In the blood of an adult man the total content of haemoglobin is roughly [AIIMS 2010]  
(a) Several hundred grams (b) Tens of gram (10-100g)  
(c) Several grams (d) Several hundred milligram
111. Blood plasma contains – % water [NCERT; AFMC 2008]  
(a) 60 (b) 80  
(c) 90 (d) 98
112. Normal glucose level in blood is [AFMC 2008]  
(a) 150-180 mg/100ml blood  
(b) 80-100 mg/100ml blood  
(c) 30-70 mg/100ml blood  
(d) 220-250 mg/100ml blood

113. Which of the followings are required for blood clotting  
[AFMC 2008, 10; MP PMT 2010]

- (a)  $K^+$ , thromboplastin (b)  $Ca^{++}$ , thromboplastin  
(c)  $Na^+$ ,  $Ca^{++}$  (d)  $K^+$ , prothrombin

114. Which one of the following is a matching pair of a certain body feature and its value / count in a normal human adult  
[AIIMS 2007, 08]

- (a) Urea – 5–10 mg/100mL of blood  
(b) Blood sugar (fasting) – 70–100 mg/100mL.  
(c) Total blood volume – 5–6  
(d) ESR in Wintrobe method – 9–15 mm in males and 20–34 mm in females

115. About 97% of  $O_2$  is transported by RBC. The remaining 3% is  
[NCERT; Kerala PMT 2008]

- (a) Dissolved in plasma and transported  
(b) Remains in lungs  
(c) Attached to cell membranes  
(d) Inside the mitochondria  
(e) In peroxisomes

116. Multi-lobed nucleus and granular cytoplasm are characteristics of which of the following types of WBCs  
[Odisha JEE 2010]

- (a) Neutrophils (b) Monocytes  
(c) Lymphocytes (d) Eosinophils

117. In normal healthy individuals the percentage of adult and fetal haemoglobin, HbA : HbA2 : HbF is [AMU (Med.) 2009]

- (a) 96 : 2 : 2 (b) 45 : 45 : 10  
(c) 50 : 45 : 5 (d) 80 : 10 : 10

118. The majority of  $CO_2$  is transported into blood as  
[CPMT 2009]

- (a) Bicarbonate (b) Sulphate  
(c) Oxalate (d) Citrate

119. Which of the following prevents the conversion of prothrombin to thrombin in an undamaged blood vessel  
[KCET 2009]

- (a) Heparin (b) Calcium ions  
(c) Thromboplastin (d) Fibrinogen

120. What is true about RBCs in humans [CBSE PMT (Pre.) 2010]

- (a) They do not carry  $CO_2$  at all  
(b) They carry about 20–25 percent of  $CO_2$   
(c) They transport 99.5 percent of  $O_2$   
(d) They transport about 80 percent oxygen only and the rest 20 percent of it is transported in dissolved state in blood plasma

121. Which one of the following plasma is involved in the coagulation of blood [NCERT; CBSE PMT (Pre.) 2011]

- (a) Fibrinogen (b) An albumin  
(c) Serum amylase (d) A globulin

122. Adult human RBCs are enucleate. Which of the following statement (s) is/are not most appropriate explanation for this feature

- (A) They do not need to reproduce  
(B) They are somatic cells  
(C) They do not metabolize  
(D) All their internal space is available for oxygen transport  
Options [NEET 2017]

- (a) Only (D) (b) Only (A)  
(c) (A), (C) and (D) (d) (B) and (C)

## Muscular tissue

1. Which of the following ion is necessary for the contraction of a muscles and nerve impulse transmission

[CPMT 1995; RPMT 1995; BHU 2005]

- (a)  $Na^+$  (b)  $K^+$   
(c)  $Ca^{++}$  and  $Mg^{++}$  ions (d) None of these

2. Which one of the following pairs of chemical substances, is correctly categorised [NCERT; CBSE PMT (Mains) 2012]

- (a) Calcitonin and thymosin -Thyroid hormones  
(b) Pepsin and prolactin-Two digestive enzymes secreted in stomach  
(c) Troponin and myosin-Complex proteins in striated muscles  
(d) Secretin and rhodopsin -Polypeptide hormones

3. Shivering with cold in winter is caused by [MP PMT 2001]

- (a) Voluntary action of striated muscles  
(b) Voluntary action of unstriated muscles  
(c) Involuntary action of striated muscles  
(d) Involuntary action of unstriated muscles

4. Unstriated muscles are found in

- (a) Neck (b) Urinary bladder  
(c) Arms (d) Fingers

5. Cardiac muscles are having characters of

- (a) Striped muscle (b) Unstriated muscle  
(c) Both (a) and (b) (d) None of these

6. Unstriated smooth muscles are found in

- (a) Thigh (b) Eye muscles  
(c) Iris (d) Tongue

7. Sarcolemma is the covering of [MP PMT 2003]

- (a) Nerve fibres (b) Muscle fibres  
(c) Bone marrow (d) Liver, kidney and stomach

8. Sliding filament theory can be best explained as

[AIPMT (Cancelled) 2015]

- (a) Actin and Myosin filaments shorten and slide pass each other  
(b) Actin and Myosin filaments do not shorten but rather slide pass each other  
(c) When myofilaments slide pass other, Myosin filaments shorten while actin filaments do not shorten  
(d) When myofilaments slide pass each other actin filaments shorten while myosin filament do not shorten

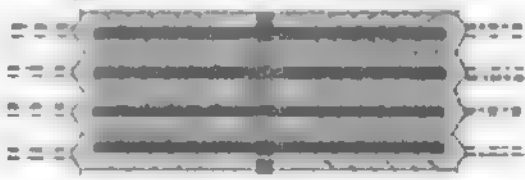
9. Which of the following makes heart wall more thick

[Odisha JEE 2011]

- (a) Pericardium (b) Epicardium  
(c) Myocardium (d) Endocardium

10. Who propounded the "Sliding filament theory" for muscles contraction

- (a) Cori  
(b) H.E. Huxley  
(c) A.F. Huxley  
(d) H.E. Huxley and A.F. Huxley

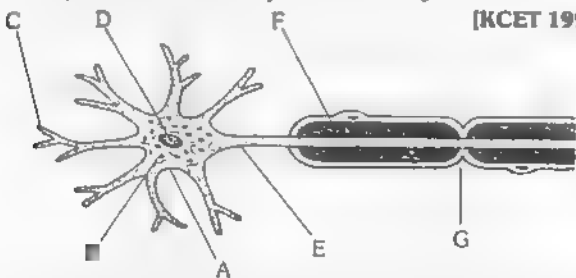
11. In the thin filament of skeletal muscle fibre, a small globular protein, that masks the active sites on the F-actin is  
[Kerala PMT 2007, 08]  
(a) G-actin (b) Actin  
(c) Tropomyosin (d) Troponin  
(e) Myosin
12. During muscular contraction, which of the following events occur  
(i) H-zone disappears (ii) A band widens  
(iii) I band reduces in width  
(iv) Width of A band is unaffected  
(v) M line and Z line come closer  
[EAMCET 2009; AIIMS 2012]  
(a) (i), (iii), (iv) and (v) (b) (i), (ii) and (v)  
(c) (ii), (iv) and (v) (d) (i), (ii) and (iii)
13. Epimysium, perimysium and endomysium are found in  
[MP PMT 2009]  
(a) Nerve (b) Blood vessel  
(c) Striated muscle (d) Uterus
14. Striped muscles have  
(a) One nucleus (b) Many nuclei  
(c) Two nuclei (d) No nuclei
15. Oxygen dissociation curve for myoglobin is [AFMC 2008]  
(a) Sigmoidal (b) Hyperbolic  
(c) Linear (d) Parabolic
16. The protein which maintains the muscular storage of oxygen is  
[CMC Vellore 1993; WB JEE 2011]  
(a) Myoglobin (b) Actomyosin  
(c) Myosin (d) Haemoglobin
17. The interval between the beginning of electrical response and peak of tension recorded is the [CMC Vellore 1993]  
(a) Latent period (b) Contraction time  
(c) Relaxation time (d) None of these
18. Autorhythmicity is a special property of the muscles of the  
[KCET 1994]  
Or  
Striped and branched muscle are found in [CPMT 1994]  
(a) Liver (b) Intestine  
(c) Heart (d) Kidney
19. Which of the following is the example of structural protein  
[RPMT 2006]  
(a) Myosin (b) Collagen  
(c) Keratin (d) All of these
20. Smooth muscle fibres are [JIPMER 1993]  
(a) Cylindrical, unbranched, striated, multinucleate and voluntary  
(b) Spindle-shaped, unbranched, non-striated, uninucleate and involuntary  
(c) Cylindrical, unbranched, non-striated, multinucleate and involuntary  
(d) Spindle-shaped, unbranched, striated, uninucleate and voluntary
21. The most abundant tissue in the body is [DPMT 1993]  
Or  
Which tissue is most widely distributed in the body forming major part  
Or  
In metazoa one of the following is responsible for locomotion and movement of organs [MP PMT 2001]  
(a) Nervous (b) Muscular  
(c) Vascular (d) Epithelial
22. All or none law is not applicable for [WB JEE 2012]  
(a) Whole skeletal muscle  
(b) Single skeletal muscle fibre  
(c) Whole cardiac muscle  
(d) Single smooth muscle fibre
23. The muscles immune to fatigue are  
(a) Striped (b) Unstriated  
(c) Cardiac (d) None of these
24. State the condition of muscle contraction in following diagram [GUJCET 2015]
- 
- (a) Resting potential (b) Contraction  
(c) Maximally contracted (d) None
25. Striated and voluntary muscle fibres are found in [MP PMT 1999]  
(a) Lungs (b) Leg muscles  
(c) Gall bladder (d) Blood vessels
26. Ciliary muscles are which  
Or  
Ciliary muscles are contractile structures which  
(a) Move cilia of some protozoans  
(b) Keep valves of heart intact  
(c) Change focal length of human eye and are found at joint of sclera and iris  
(d) Cause erection of human hairs in cold and are situated in skin
27. 'Oxygen debt' is amount of oxygen required for  
(a) Muscle contraction (b) Muscle relaxation  
(c) Muscle recovery (d) All the above
28. In the resting muscle fibre tropomyosin partially covers [AMU (Med.) 2010]  
(a) Ca binding sites on troponin  
(b) Actin binding sites on myosin  
(c) Myosin binding sites on actin  
(d) Ca binding sites on actin

29.  $\text{Na}^+ - \text{K}^+$  pump is found in membranes of many cells, like nerve cells. It works against electro chemical gradient and involve an integral protein ATPase. For each molecule of ATP used [AFMC 2006]
- 3 ions of  $\text{Na}^+$  are pumped out and two  $\text{K}^+$  are taken in
  - 3 ions of  $\text{Na}^+$  are taken in and  $2\text{K}^+$  are pumped out
  - 2 ions of  $\text{Na}^+$  are thrown out and  $3\text{K}^+$  are absorbed
  - 3 ions of  $\text{K}^+$  are absorbed and  $3\text{Na}^+$  are pumped out
30. The 'thick' filament in muscles is polymerised protein of [Kerala PMT 2012]
- Meromyosins
  - Actins
  - Troponins
  - Tropomyosins
  - Keratin
31. Actin filament is made up of [BHU 2003]
- Actin, troponin and tropomyosin
  - Actin, troponin
  - Myosin, troponin
  - Actin, tropomyosin
32. Krause membrane or Z – line is a myofibril which separates two adjacent [CBSE PMT 2001; MP PMT 2002; Kerala PMT 2009]
- Sarcomeres
  - H – zones
  - I – bands
  - A – bands
33. The muscles which can retract are [CPMT 1998]
- Retractor
  - Protractor
  - Abductor
  - All of these
34. Read the statements regarding muscle proteins
- Actin is a thin filament and is made up of two F-actins
  - The complex protein, tropomyosin is distributed at regular intervals on the troponin
  - Myosin is a thick filament which is also a polymerized protein
  - The globular head of meromyosin consists of light meromyosin (LMM)
- Of the above statements [Kerala PMT 2010]
- (A), (B) and (C) are correct
  - (A), (B) and (D) are correct
  - (A) and (C) are correct
  - (B) and (D) are correct
  - (B), (C) and (D) are correct
35. Actin and myosin proteins are related with [BVP 2001]
- $\text{Na}^+$  and  $\text{K}^+$  pump
  - Muscle contraction
  - Nervous system
  - Excretion of water products
36. Myoglobin is found in [MP PMT 1997; AFMC 2000, 12; Pb. PMT 2000]
- Muscles
  - Blood
  - Liver
  - Spleen
37. Statements
- A – bands of the muscle is dark and contain myosin
  - I – bands are the light bands and contain actin
  - During muscle contraction the A – band contracts
  - The part between the two Z – lines is called as sarcomere
  - The central part of thin filament, not overlapped by thick filament is called H-zone
- Of the above statements [Kerala PMT 2007]
- A, B and C are correct while D and E are incorrect
  - A, C, E are correct while B, D are incorrect
  - A and B are correct while C, D and E are incorrect
  - A, B, C and E are correct while D is incorrect
  - A, B and D are correct while C and E are incorrect
38. The structural and functional unit of the striated muscle fibre is called [CBSE PMT 1998]
- Sarcolemma
  - Sarcomere
  - Sarcoplasm
  - Myofibril
39. Hypertrophy of muscle is
- Muscles become thin and weak due to excessive work
  - Muscles become thick and strong due to excessive work
  - Muscles become thin and weak due to no work
  - Muscles become thick and strong due to no work
40. Action potential is generated by [MP PMT 2007]
- $\text{Na}^+$
  - $\text{K}^+$
  - $\text{Ca}^{++}$
  - $\text{Cl}^-$
41. The largest muscle in human body is [BVP 2000]
- Masseter
  - Sartorius
  - Stapedius
  - Gluteus
42. The type of muscles present in our [NCERT; CBSE PMT (Mains) 2011]
- Thigh are striated and voluntary
  - Upper arm are smooth muscle fibres fusiform in shape
  - Heart are involuntary and unstriated smooth muscles
  - Intestine are striated and involuntary
43. The ready source of energy in living cells is [CPMT 1995]
- Glucose
  - ATP
  - Glycogen
  - ADP
44. In a muscle, the functional unit of contraction is the [Kerala PMT 2012]
- Portion of myofibril between two successive 'Z' lines
  - I band
  - A band
  - H zone
  - I band with a Z line
45. Unstriated muscles are found in [RPMT 1995]
- Veins
  - Arteries
  - Uterus
  - All the above
46. Which set clearly identify striated muscles [CPMT 2005]
- Cylindrical, syncytial and unbranched
  - Spindle, unbranched and uninucleated
  - Cylindrical, striped and nucleated
  - Cylindrical, striped and branched

47. Muscular tissue is differentiated into [MP PMT 1995]  
 (a) Unstriated, striped  
 (b) Striped, cardiac  
 (c) Cardiac muscle, unstriated  
 (d) Unstriated, striated and cardiac
48. During muscular contraction [MP PMT 1996]  
 (a) ATP is broken down (b) ATP is formed  
 (c) GTP is broken down (d) None of these
49. The important muscle proteins that help in movement are [AMU (Med.) 2012]  
 (a) Actin and myosin (b) Tropomyosin  
 (c) Troponin (d) All of these
50. Cardiac muscle fibres differ from skeletal muscles because these are [AIIMS 2000; MP PMT 2006]  
 (a) Striated, involuntary (b) Non-striated-voluntary  
 (c) Non-striated involuntary (d) Antagonistic

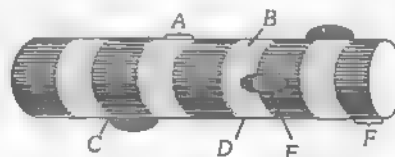
### Nervous tissue

1. Most of the neurons of our body are [AFMC 1994]  
 (a) Unipolar (b) Bipolar  
 (c) Pseudounipolar (d) Multipolar
2. Synapses store  
 (a) Stimulating chemicals (b) Inhibitory chemicals  
 (c) Conducting chemicals (d) All of these
3. Schwann cells and Node of Ranvier are found in [DPMT 1993; BHU 2003; Kerala PMT 2009]  
 (a) Nervous tissue (b) Osteoblast  
 (c) Chondrioblast (d) Gland cells
4. Which of the following is regarded as a unit of nervous tissue [CBSE PMT 1999]  
 (a) Axons (b) Dendrites  
 (c) Neurons (d) Myelin sheath
5. Dark bands are [NCERT; CPMT 2009]  
 (a) A-band (b) B-band  
 (c) I-band (d) Z-line
6. In the diagram of multipolar myelinated neuron given below, different parts have been indicated by alphabets; choose the answers in which these alphabets have been correctly matched with the parts which they indicate [KCET 1999]



- (a) A=Cell body, B=Nissl bodies, C=Nucleus, D=Dendrites, E=Naked portion of axon, F=Myelin sheath, G=Node of Ranvier
- (b) A=Cell body, B=Nissl bodies, C=Naked portion of axon, D=Dendrites, E=Nucleus, F=Myelin sheath, G=Node of Ranvier
- (c) A=Cell body, B=Nissl bodies, C=Naked portion of axon, D=Nucleus, E=Dendrites, F=Myelin sheath, G=Node of Ranvier
- (d) A=Cell body, B=Nissl bodies, C=Dendrites, D=Nucleus, E=Naked portion of axon, F=Myelin sheath, G=Node of Ranvier

7. Irritability and conductivity are maximum developed in  
 (a) Muscular tissue (b) Nervous tissue  
 (c) Connective tissue (d) None of the above
8. Nerve cell originated from embryonic  
 (a) Ectoderm (b) Mesoderm  
 (c) Both (a) and (b) (d) Endoderm
9. Longest cell in human body may be [MP PMT 1998]  
 (a) Nerve cell (b) Leg muscle cell  
 (c) Bone cell (d) Heart muscle cell
10. Nerve fibre is different from the muscle fibre due to the presence of  
 (a) Myofibrils (b) Lines  
 (c) Sarcolemma (d) Dendrites
11. The area where the medullary sheath is absent in the nerve fibre is called [CPMT 2009]  
 (a) Schwann cells (b) Schwann nodes  
 (c) Nissl Granules (d) Node of Ranvier
12. Nodes of Ranvier are found in [DPMT 2006; MP PMT 2011]  
 (a) Non-myelinated nerve fibres  
 (b) Myelinated nerve fibres  
 (c) Both (a) and (b)  
 (d) None of the above
13. Neurons with long axons are called  
 (a) Golgi type I (b) Golgi type II  
 (c) Golgi type III (d) Golgi type IV
14. The diagram given below represents the histology of a stripped muscle. Label the parts A, B, C, D E and F [KCET 2011]



- (a) A-Sarcoplasm, B-Nucleus, C-Sarcolemma, D-myofibril, E-Dark band, F-Light band
- (b) A-Sarcoplasm, B-Light band, C-Myofibril, D-Sarcolemma, E-Nucleus, F-Dark band
- (c) A-Light band B-Sarcoplasm, C-Myofibril, D-Sarcolemma, E-Nucleus, F-Dark band
- (d) A-Sarcolemma, B-Nucleus, C-Dark band, D-Light band, E-Sarcoplasm, F-Myofibril
15. Which of the damaged cells can not be repaired [AFMC 2006]  
 (a) Liver cells (b) Brain cells  
 (c) Bone cells (d) Epidermal cells
16. Non-excitabile cells, found among the neurons are called [CPMT 2003]

Or

Which of the following is not the cell of areolar tissue

[KCET 2001]

- (a) Dendrite (b) Axon  
 (c) Schwann's cells (d) Nissl's body
17. Myelin sheath is a layer covering [CMC Vellore 1993]  
 (a) A nerve fibre in an insect  
 (b) A chick embryo  
 (c) A muscle fibre in a vertebrate  
 (d) A nerve fibre in a vertebrate

18. Myelin sheath is covering of  
(a) Muscle cells (b) Axon of neurons  
(c) Blood vessels (d) Osteocytes
19. The junction between Schwann cells is known as [MP PMT 1992]  
(a) Plasmalemma (b) Node of Ranvier  
(c) Dendrons (d) Synapse
20. Myelin sheath is formed by [NCERT; CPMT 2010]  
(a) Ranvier cells (b) Muscle cells  
(c) Schwann cells (d) Axon
21. The junction between the axon of one neuron and the dendrite of the next is called [NCERT; CBSE PMT 1999; CPMT 2001; AFMC 2003; MP PMT 2003; Odisha JEE 2011]  
**Or**  
Junction of two nerve fibres is called [MP PMT 2007]  
(a) A joint (b) A synapse  
(c) Constant bridge (d) Junction point
22. Nissl's granules are found in cyton of nerve cells. These have affinity for basic dyes. The granules are made up of [MP PMT 1992, 97; CBSE PMT 2003; DPMT 2006]  
(a) Mitochondria (b) Cell metabolites  
(c) Fat granules (d) Ribosomes
23. The afferent process of neuron is known as  
(a) Axon (b) Dendrite  
(c) Cyton (d) Neurofibrillae
24. Which of the following tissues in mammals show the least capacity for regeneration [CPMT 1995, 97; RPMT 2005, 06]  
(a) Epithelial tissue of the skin  
(b) Endothelium of blood vessels  
(c) Skeletal tissue of long bones  
(d) Nervous tissue of brain
25. Schwann cell is found around [BHU 2003]  
(a) Axon (b) Cyton  
(c) Dendrite (d) Dendron
26. The most appropriate definition of Neuroglial cells are that they are [Kerala CET 2003]  
(a) Nonsensory supporting cells  
(b) Secretory cells  
(c) Sensory cells  
(d) Sensory and supporting cells
27. End plate junction is present between [CPMT 2010]  
(a) Neuron and striated muscle  
(b) Neuron and neuron  
(c) Muscle and muscle  
(d) Both (b) and (c)
28. Nerve fibres conduct impulses in [RPMT 1999]  
(a) One direction (b) Two direction  
(c) Multidirection (d) None of the above
29. Which one of the following is not essentially a part of nervous system [CPMT 1998]  
(a) Cyton (b) Axon  
(c) Myelinated (d) Intermedin



NCERT

## Exemplar Questions

1. Which one of the following types of cell is involved in making of the inner walls of large blood vessels [NCERT]  
(a) Cuboidal epithelium (b) Columnar epithelium  
(c) Squamous epithelium (d) Stratified epithelium
2. To which one of the following categories does adipose tissue belong [NCERT]  
(a) Epithelial (b) Connective  
(c) Muscular (d) Neural
3. Which one of the following is not a connective tissue [NCERT]  
(a) Bone (b) Cartilage  
(c) Blood (d) Muscles
4. Which one of the following statements is true for cockroach [NCERT]  
(a) The number of ovarioles in each ovary are ten  
(b) The larval stage is called caterpillar  
(c) Anal styles are absent in females  
(d) They are ureotelic
5. Match the followings and choose the correct option  
A. Adipose tissue I. Nose  
B. Stratified epithelium II. Blood  
C. Hyaline cartilage III. Skin  
D. Fluid connective tissue IV. Fat storage  
Options [NCERT]  
(a) A-I, B-II, C-III, D-IV  
(b) A-IV, B-III, C-I, D-II  
(c) A-III, B-I, C-IV, D-II  
(d) A-II, B-I, C-IV, D-III
6. Match the followings and choose the correct answer  
A. Hermaphrodite I. Produces blood cells and haemoglobin  
B. Direct development II. Testis and ovary in the same animal  
C. Chemoreceptor III. Larval form absent  
D. Blood gland in earthworm IV. Sense of chemical substances  
Options [NCERT]  
(a) A-II, B-III, C-IV, D-I  
(b) A-III, B-II, C-IV, D-I  
(c) A-I, B-III, C-II, D-I  
(d) A-II, B-IV, C-III, D-I
7. Match the following with reference to Cockroach and choose the correct option  
A. Phallomere I. Chain of developing ova  
B. Gonopore II. Bundles of sperm  
C. Spermatophore III. Opening of the ejaculatory duct  
D. Ovarioles IV. The external genitalia  
Options [NCERT]  
(a) A-III, B-IV, C-II, D-I  
(b) A-IV, B-III, C-II, D-I  
(c) A-IV, B-II, C-III, D-I  
(d) A-II, B-IV, C-III, D-I

8. Match the followings and choose the correct answer
- |                      |                               |
|----------------------|-------------------------------|
| A. Touch             | i. Nasal epithelium           |
| B. Smell             | ii. Foramen magnum            |
| C. Cranial nerves    | iii. Sensory papillae         |
| D. Medulla oblongata | iv. Peripheral nervous system |
- Options [NCERT]
- (a) A-iii, B-i, C-ii, D-iv  
 (b) A-ii, B-i, C-iv, D-iii  
 (c) A-iii, B-iv, C-ii, D-i  
 (d) A-iii, B-i, C-iv, D-ii

## Critical Thinking

### Objective Questions

1. Identify the correctly matched pair/pairs of the germ layers and their derivatives
- |             |   |                 |
|-------------|---|-----------------|
| A. Ectoderm | — | Epidermis       |
| B. Endoderm | — | Dermis          |
| C. Mesoderm | — | Muscles         |
| D. Mesoderm | — | Notochord       |
| E. Endoderm | — | Enamel of teeth |

[KCET 2009]

- (a) A, C and D only (b) A, B, C and E only  
 (c) A and D only (d) A and B only

2. Match list I with list II and find the correct option

List I	List II
(Epithelial tissue)	(Location)
(A) Cuboidal	(1) Epidermis of skin
(B) Ciliated	(2) Inner lining of blood vessels
(C) Columnar	(3) Inner surface of gall bladder
(D) Squamous	(4) Inner lining of Fallopian tube
(E) Keratinized squamous	(5) Lining of pancreatic duct

[Pb PMT 1999, 2009; BHU 2003; Kerala PMT 2009, 11]

- (a) (A) — (5), (B) — (4), (C) — (2), (D) — (3), (E) — (1)  
 (b) (A) — (3), (B) — (4), (C) — (5), (D) — (2), (E) — (1)  
 (c) (A) — (5), (B) — (4), (C) — (3), (D) — (2), (E) — (1)  
 (d) (A) — (3), (B) — (4), (C) — (5), (D) — (1), (E) — (2)  
 (e) (A) — (3), (B) — (5), (C) — (4), (D) — (1), (E) — (2)

3. Which one of the following mammalian cells is not capable of metabolising glucose to carbon-dioxide aerobically

[CBSE PMT 2007]

- (a) White blood cells (b) Unstriated muscle cells  
 (c) Liver cells (d) Red blood cells

4. An epithelial tissue which has thin and flat cells arranged edge to edge so as to appear like closely packed tiles, is found at the

[CBSE PMT 1994; 2000]

- (a) Inner lining of stomach  
 (b) Inner lining of cheeks  
 (c) Outer surface of ovary  
 (d) Inner lining of fallopian tube

5. In heart cells, which one serves as a second messenger, speeding up muscle cell contraction in response to adrenaline

[Kerala PMT 2006]

- (a) cAMP (b) cGMP  
 (c) GTP (d) ATP  
 (e) AMP

6. Stratum germinativum is an example of which kind of epithelium [CBSE PMT 1997]

- (a) Cuboidal (b) Ciliated  
 (c) Columnar (d) Squamous

7. Select proper option, by matching column I, II and III

Column I (Common Name)	Column II (Roman Numerical Designation)	Column III (Activation product)
(P) Prothrombin	(x) I	(i) Convertin
(Q) Proconvertin	(y) V	(ii) Fibrin
(R) Fibrinogen	(z) II	(iii) Thrombin
(S) Proaccelerin	(w) VII	(iv) Accelerin

[GUJCET 2015]

- (a) (P - z - iii) (Q - w - i) (R - y - ii) (S - x - iv)  
 (b) (P - w - ii) (Q - z - iii) (R - y - iv) (S - x - i)  
 (c) (P - z - iii) (Q - w - ii) (R - x - iv) (S - y - i)  
 (d) (P - z - iii) (Q - w - i) (R - x - ii) (S - y - iv)

8. Match List - I and List - II and select the correct option

	List - I		List - II
A.	Biological pigments	1.	Sodium chloride
B.	Chemical messengers	2.	Steroids
C.	Important constituent of blood	3.	Prostaglandins
D.	Four carbon rings	4.	Terpenes

[Kerala PMT 2007]

- (a) A - 2, B - 4, C - 3, D - 1 (b) A - 2, B - 1, C - 4, D - 3  
 (c) A - 3, B - 4, C - 2, D - 1 (d) A - 4, B - 3, C - 1, D - 2  
 (e) A - 3, B - 4, C - 1, D - 2

9. Statements

- A. Plasma constitutes 45% of the human blood  
 B. Albumin is a plasma protein which helps in osmotic balance  
 C. Factors responsible for the blood clotting process are present in the blood  
 D. Plasma without clotting factors is called serum  
 E. Minerals are not generally found in blood

Of the above statements

[Kerala PMT 2007]

- (a) Only E is wrong and all other A to D are correct  
 (b) A and B are correct and C, D and E are wrong  
 (c) B and D are correct and A, C and E are wrong  
 (d) A and E are correct and B, C and D are wrong  
 (e) B, C and D are correct and A and E are wrong

10. Processes from osteoblasts are called [MP PMT 2000]

- (a) Dendrites (b) Lamellae  
 (c) Canaliculi (d) Haversian canals

11. The major protein of the connective tissues is

[DPMT 1993; AIIMS 2001]

- (a) Keratin (b) Collagen  
 (c) Melanin (d) Myosin

12. The colour in the brown fat is due to

- (a) Its larger capacity for generating heat  
 (b) Large number of mitochondria present  
 (c) A high concentration of iron containing cytochrome pigments  
 (d) Presence of chromatophores

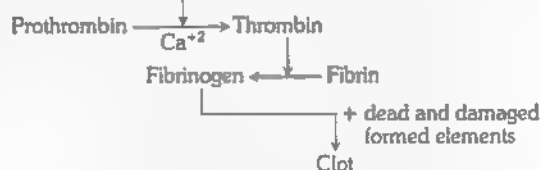
13. Choose the correctly matched pair [CBSE PMT 2014]  
 (a) Tubular parts of nephrons-Cuboidal epithelium  
 (b) Inner surface of bronchioles-Squamous epithelium  
 (c) Inner lining of salivary ducts-Ciliated epithelium  
 (d) Moist surface of buccal cavity-Glandular epithelium

14. The protein whose removal enables myosin to bind actin in smooth muscle is [J & K CET 2012]

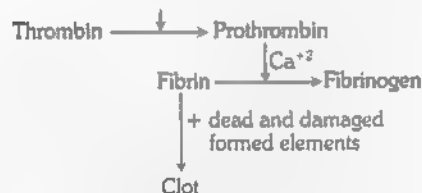
- (a) Tropomyosin (b) Caldesmon  
 (c) Myosin light chain kinase (d) Calmodulin

15. Which pathway is correct for blood clotting [NCERT]

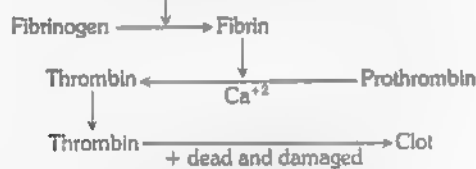
- (a) Thromboplastin or Thrombokinase



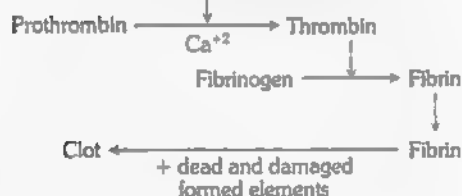
- (b) Thromboplastin or Thrombokinase



- (c) Thromboplastin or Thrombokinase



- (d) Thromboplastin or Thrombokinase  
 (from injured platelets / tissues)



16. Match the following

'A'

- A. Barr body  
 B. Purkinje cells  
 C. Nissl bodies  
 D. Schwann cell

'B'

1. Gives a grey colour to the cell body  
 2. Conduction muscles of heart  
 3. Present in neurilemma  
 4. Certain neurons having flask shaped cytons  
 5. Found in cytons of female

The correct pairing is

- (a) 5, 4, 1, 3, 2 (b) 3, 2, 5, 1, 4  
 (c) 5, 2, 1, 3, 4 (d) 4, 3, 2, 5, 1

17. Progressive degeneration of skeletal muscle, mostly due to genetic disorder occurs in [Kerala PMT 2010]

- (a) Myasthenia gravis (b) Muscular dystrophy  
 (c) Tetany (d) Osteoporosis  
 (e) Arthritis

18. Polymorphonuclear leucocytes are [CBSE PMT 1993]

- (a) Monocytes (b) Lymphocytes  
 (c) Granulocytes (d) Agranulocytes

19. Hyaline cartilage does not have [DUMET 2010]

- (a) Fibres (b) Lacunae  
 (c) Cells (d) Blood capillaries

20. In human embryo, main haemopoietic tissue is [CPMT 1993]

- (a) Spleen (b) Liver  
 (c) Bone marrow (d) Kidney

21. Platelets release during blood clotting is [EAMCET 1998]

- (a) Thrombin (b) Prothrombin  
 (c) Thrombokinase (d) Fibrinogen

22. Lymph contains

- (a) Only leucocytes  
 (b) 99% lymphocytes, no RBCs and other leucocytes  
 (c) 50% leucocytes and 50% erythrocytes  
 (d) 99% erythrocytes and 1% small lymphocytes

23. Bundles of striated muscle fibres called fasciculi are enclosed by a sheath called

- (a) Epimysium (b) Endomysium  
 (c) Perimysium (d) Peritoneum

24. The value of resting membrane potential is

[DPMT 1993; Kerala PMT 2006]

- (a) -90mV (b) -100mV  
 (c) +100mV (d) +90mV

25. The triceps and biceps muscles are of

- (a) Antagonist type (b) Involuntary type  
 (c) Smooth type (d) Sphincter type

26. Poisons like cyanide inhibit  $\text{Na}^+$  efflux and  $\text{K}^+$  influx during cellular transport. This inhibitory effect is reversed by an injection of ATP. This demonstrates that [CBSE PMT 1994]

- (a) ATP is the carrier protein in the transport system  
 (b)  $\text{Na}^+ - \text{K}^+$  exchange pump operates in the cell  
 (c) ATP is hydrolysed by ATPase to release energy  
 (d) Energy for  $\text{Na}^+ - \text{K}^+$  exchange pump comes from ATP

27. Actin binding sites are located on [Kerala PMT 2011]

- (a) Troponin  
 (b) Tropomyosin  
 (c) Meromyosin  
 (d) Both tropomyosine and meromyosin  
 (e) Both troponin and tropomyosin

28. Lack of relaxation between successive stimuli in sustained muscle contraction is known as [NEET (Phase-I) 2016]

- (a) Spasm (b) Fatigue  
 (c) Tetanus (d) Tonus

29. Which type of tissue correctly matches with its location

[NEET (Phase-I) 2016]

Tissue	Location
(a) Smooth muscle	Wall of intestine
(b) Areolar tissue	Tendons
(c) Transitional epithelium	Tip nose
(d) Cuboidal epithelium	Lining of Stomach



# R Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

- (a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion  
 (b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion  
 (c) If the assertion is true but the reason is false  
 (d) If both the assertion and reason are false  
 (e) If the assertion is false but reason is true

1. Assertion : Total count of RBC comes out to be very low in polycythemia.  
 Reason : Number of erythrocytes get reduced in the condition of polycythemia
2. Assertion : Haemoglobin is said to be a conjugated protein.  
 Reason : It is composed of a protein called haem and a non protein iron porphyrin complex called globin.
3. Assertion : Histamine is involved in allergic and inflammatory reactions.  
 Reason : Histamine is a vasodilator [AIIMS 2002]
4. Assertion : Chilling of blood decreases coagulation time.  
 Reason : Cold depresses the action of coagulation promoting enzymes
5. Assertion : Thrombin is necessary to initiate blood coagulation.  
 Reason : Thrombin helps in the formation of thromboplastins.
6. Assertion : Mast cells in the human body release excessive amounts of inflammatory chemicals which cause allergic reactions.  
 Reason : Allergens in the environment on reaching human body stimulate mast cells in certain individuals. [AIIMS 2003, 07]
7. Assertion : The regulation of RBC production is accomplished by FSH  
 Reason : Erythropoietin, hormone circulates to red bone marrow where it increases stem cell mitosis and speed up development of RBCs. [AIIMS 2002]
8. Assertion : Muscle cells are also called myofibrils.  
 Reason : Muscle cells are very thin and elongated
9. Assertion : Thigh muscles can get tired but not the muscles of ventricle of heart.  
 Reason : Muscles of thigh are voluntary whereas that of heart are involuntary muscles.
10. Assertion : WBCs accumulate at site of wounds by diapedesis  
 Reason : It is squeezing of leucocytes from endothelium. [AIIMS 2002]

11. Assertion : Non-striated muscles are said to be voluntary in nature.  
 Reason : Non-striated muscles can be moved according to will.
12. Assertion : Intercalated discs are important regions of cardiac muscle cells.  
 Reason : Intercalated discs function as boosters for muscle contraction waves.
13. Assertion : Presence of connective tissue inside the brain is essential for conduction of nerve impulse.  
 Reason : Connective tissue hold together the nerve cells of brain.
14. Assertion : Histamine is related with allergic and inflammatory reactions.  
 Reason : Histamine is a vasodilator.
15. Assertion : Non-myelinated nerve fibres do not possess nodes of Ranvier.  
 Reason : This is due to the absence of nissl's bodies in node of Ranvier.
16. Assertion : Specialization of cells is advantageous for the organism  
 Reason : It increase the operational efficiency of an organism. [AIIMS 2002]
17. Assertion : Cartilage (protein matrix) and bone (calcium matrix) are rigid connective tissue.  
 Reason : Blood is connective tissue in which plasma is the matrix. [AIIMS 2001, 13]
18. Assertion : Materials can not be exchanged between epithelial cells  
 Reason : Blood vessels are absent in epithelial tissue.
19. Assertion : The cells of columnar epithelium in absorptive surfaces often bears microvilli on their free ends.  
 Reason : Microvilli on their free ends.
20. Assertion : Fatigue is the inability of a muscle to relax.  
 Reason : It is due to lactic acid accumulation by repeated contraction. [AIIMS 1998]
21. Assertion : Fibroblasts help in protection.  
 Reason : Fibroblasts synthesize two kinds of protein which are protective in nature.
22. Assertion : Bones possess longitudinal canals called lacunae  
 Reason : Lacunae carry blood vessels & nerves to the bones.
23. Assertion : Deposits of protein keratin are present in deeper layers of stratified keratinised squamous epithelium.  
 Reason : Keratin makes this epithelium impervious to water
24. Assertion : Extracellular materials are important for cells  
 Reason : Intercellular materials surround the cells & bind them together

- 25. Assertion :** Simple epithelium covers surfaces exposed to mechanical or chemical abrasions.  
**Reason** Protection of underlying tissues is the major function of simple epithelium.
- 26. Assertion :** Tendon is present in all bone joints.  
**Reason** Tendon connects the bones at the joints & hold them in position.
- 27. Assertion :** Urinary bladder can considerably expand to accommodate urine.  
**Reason** It is lined by stretchable squamous epithelium.
- 28. Assertion :** Granulocytes are white blood cells.  
**Reason** They contain lobed nuclei and tiny granules. [AIIMS 2010]
- 29. Assertion :** Columnar epithelium lining the intestinal mucosa appears to have a brush like appearance.  
**Reason** A large number of microvilli are present on brush bordered columnar epithelium.
- 30. Assertion** The regulation of RBC production is accompanied by the kidneys.  
**Reason** Erythropoietin hormone circulates to the red bone marrow, where it increases stem cell mitosis and speeds up the development of RBCs. [AIIMS 2009]

## Answers

### Epithelial tissue

1	a	2	b	3	d	4	d	5	c
6	a	7	c	8	a	9	b	10	a
11	a	12	b	13	c	14	d	15	d
16	b	17	a	18	c	19	b	20	a
21	a	22	a	23	c	24	a	25	d
26	a	27	a	28	c	29	b	30	d
31	b	32	d	33	c	34	e	35	d
36	c	37	a	38	c	39	b	40	b
41	d	42	a						

### Connective tissue

1	b	2	b	3	d	4	d	5	c
6	a	7	d	8	c	9	a	10	d
11	d	12	a	13	b	14	c	15	d
16	d	17	a	18	d	19	a	20	d
21	a	22	a	23	c	24	d	25	c
26	d	27	d	28	a	29	b	30	a
31	c	32	c	33	b	34	a	35	c
36	c	37	d	38	a	39	d	40	c
41	b	42	c	43	a	44	b	45	d

### Skeletal tissue

1	c	2	b	3	b	4	b	5	a
6	b	7	a	8	c	9	a	10	d
11	b	12	d	13	c	14	b	15	a
16	a	17	b	18	d	19	a	20	d
21	b	22	b	23	b	24	c		

### Vascular tissue

1	c	2	c	3	a	4	a	5	b
6	c	7	d	8	b	9	b	10	d
11	c	12	b	13	b	14	a	15	b
16	a	17	c	18	a	19	a	20	c
21	d	22	d	23	c	24	a	25	b
26	b	27	b	28	c	29	c	30	a
31	b	32	a	33	c	34	b	35	c
36	c	37	c	38	a	39	c	40	a
41	a	42	c	43	a	44	a	45	b
46	a	47	c	48	c	49	b	50	c
51	d	52	b	53	a	54	c	55	c
56	b	57	a	58	b	59	b	60	b
61	d	62	a	63	b	64	c	65	a
66	d	67	b	68	b	69	b	70	b
71	b	72	b	73	c	74	a	75	d
76	a	77	b	78	b	79	b	80	c
81	b	82	a	83	c	84	c	85	b
86	a	87	a	88	a	89	c	90	a
91	c	92	b	93	c	94	b	95	b
96	a	97	d	98	c	99	a	100	a
101	c	102	b	103	b	104	c	105	b
106	d	107	a	108	c	109	c	110	a
111	c	112	b	113	b	114	b	115	a
116	a	117	a	118	a	119	a	120	b
121	a	122	c						

### Muscular tissue

1	c	2	c	3	c	4	b	5	c
6	c	7	b	8	b	9	c	10	d
11	d	12	a	13	c	14	b	15	b
16	a	17	a	18	c	19	d	20	b
21	b	22	a	23	c	24	c	25	b
26	c	27	c	28	c	29	a	30	a
31	a	32	a	33	d	34	c	35	b

36	a	37	e	38	b	39	b	40	a
41	d	42	a	43	b	44	a	45	d
46	a	47	d	48	a	49	d	50	a

**Nervous tissue**

1	d	2	d	3	a	4	c	5	a
6	d	7	b	8	a	9	a	10	d
11	d	12	b	13	a	14	c	15	b
16	c	17	d	18	b	19	b	20	c
21	b	22	d	23	b	24	d	25	a
26	a	27	a	28	a	29	d		

**NCERT Exemplar Questions**

1	c	2	b	3	d	4	c	5	b
6	a	7	b	8	d				

**Critical Thinking Question**

1	a	2	c	3	d	4	b	5	a
6	c	7	d	8	d	9	e	10	c
11	b	12	c	13	a	14	b	15	d
16	a	17	b	18	c	19	a	20	b
21	c	22	b	23	c	24	a	25	a
26	a	27	c	28	c	29	a		

**Assertion and Reason**

1	d	2	c	3	a	4	e	5	c
6	a	7	e	8	e	9	b	10	b
11	d	12	a	13	d	14	a	15	c
16	a	17	b	18	e	19	a	20	e
21	a	22	d	23	e	24	a	25	d
26	d	27	c	28	b	29	a	30	a

# S Answers and Solutions

**Epithelial tissue**

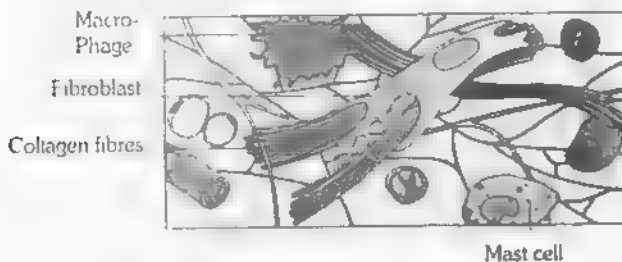
9. (b) Villi of intestine provide a velvety appearance and greatly increase the absorptive surface
10. (a) Specialized cuboidal cells capable of producing gametes are found in gonads. Germinal epithelium produces gametes e.g., ova (female gamete) and sperm (male gamete).
11. (a) It is the mucous membrane of nasal passage
12. (b) The ciliated epithelium in trachea, is infact pseudostratified ciliated epithelium having long ciliated columnar cells and short cuboidal cells.

13. (c) Cells of squamous epithelium are flattened scale like and attached to each other like a mosaic.
15. (d) Stratified squamous epithelium occurs at surfaces subject to abrasion but protected from drying. Thus it forms the cornea of eyes, inner surfaces of eye lid, and the lining of buccal cavity, lower part of pharynx, oesophagus, vagina and vestibule of nasal cavities.
16. (b) Epithelial tissues have a widespread distribution throughout the body and serve several important functions such as protection, secretion, sensation and absorption.
17. (a) Cells of simple epithelial tissue are arranged in a single layer.
18. (c) The outer most layer in epidermis of skin consist of keratinized stratified squamous epithelium cells. These cells slowly become dead, non nucleated and water proof.
21. (a) Cells of epithelium are set very close to each other, neighbouring cells are held together by cell junctions or desmosomes
22. (a) In apocrine glands, secretory products accumulate at the apical margin. It pinches off from rest of the cell. The cell repairs the lost part, e.g., mammary gland.
23. (c) On the basis of mode of secretion pancreas, salivary gland and goblet cells are type of merocrine. In which secretion diffuses out through the cell surface.
26. (a) The cell of Germinal epithelium is cuboidal, which are capable of producing gametes.
27. (a) Epithelial tissue has great regeneration power because when epithelia are injured they regenerate more rapidly than other tissues and thus facilitate rapid healing of wounds.
28. (c) Ciliated columnar epithelium lines bronchioles and fallopian tubes.
29. (b) The skin epidermis of vertebrate animals is consist of keratinizing squamous epithelium in which cells of upper layer are dead with insoluble dead fibrous keratin protein.
35. (d) Epithelia regenerate more rapidly than other tissues when injured
37. (a) Keratinised epithelium protects the underlying tissues from mechanical injury.
39. (b) Simple columnar epithelium lines the stomach, the small and large intestines, the digestive glands and the gall bladder.
41. (d) Following embryonic layers give rise to
 

Ectoderm	–	Epidermis
Mesoderm	–	Mesothelium
Endoderm	–	Epithelium of alimentary canal
42. (a) Intestinal epithelium is glandular in nature and secretory in function.

### Connective tissue

1. (b) Each liver lobe is formed of hexagonal lobules surrounded by a connective tissue sheath called Glisson's capsule
4. (d) Mast cells occur in connective tissue proper, these are modified basophils of blood. Mast cells secrete heparin, histamine and serotonin
7. (d) Areolar tissue fixes skin to underlying muscles or joins integument with muscles.
8. (c) Ligaments are yellow elastic fibrous connective tissue while tendons are white collagen fibrous connective tissue.
9. (a) Collagen fibres are white formed of a protein, occur in bundles, thick nonelastic with great tensile strength.
10. (d) Adipose tissue is a specialized loose connective tissue in which the fibroblast are modified for fat storage. Prominent adipose tissue sites are subcutaneous fat (panniculus adiposus), blubber of whales and hump of camel.
13. (b) Because adipose tissue takes part in the storage of fat which has the highest calorific value.
15. (d) Three types of fibres collagen, elastic and reticular are found in connective tissue. Each fibre consist of collagen, elastin and reticulin respectively.
17. (a) Correct labelling as follows



18. (d) Areolar tissue contains fibroblast, macrophages mast cells, plasma cells, lymphocytes and adipose cells etc.
19. (a) Histiocyte is a phagocytic cell which is found in loose connective tissue
23. (c) Adipose tissue may be distinguished into two separate morphological type. White or unilocular fat and brown or multilocular fat
27. (d) Albumin is a globular protein.
31. (c) Adipocyte are fat cells, which are derived from fibroblast. These adipocyte are found in connective tissue.
33. (b) Ligament is a modified yellow elastic fibrous tissue which occur in the form of cords and binds a bone cartilage with another bone cartilage. It contains white fibres alongwith yellow fibres.
34. (a) Areolar and adipose tissue are loose connective tissue while tendon is dense connective tissue. Cartilage is specialized connective tissue.
36. (c) Macrophages engulf the invading microbes and destroy them
39. (d) It is albuminous protein which on boiling in water, changes into gelatin
40. (c) As it has a large matrix with almost all types of cells and fibres

### Skeletal tissue

1. (c) Mammalian bone is characterized by the presence of haversian system or osteon. Osteon is a basic structural unit of mammalian bone consisting of the haversian canal, lamellae and lacunae.
3. (b) The presence of haversian system is a typical character of mammalian bone.
4. (b) Bone is also a metabolically dynamic tissue which functions as a homeostatic reservoir of ions of calcium, magnesium, phosphorous etc. About 97% of total calcium of body occurs in the endoskeleton.
5. (a) Hyaline cartilage forms part of larynx, sternum, tracheal rings and nasal cartilages. Hyaline cartilage is the most abundant kind of cartilage with no fibres and transparent matrix. It is found upon articular surfaces at joints of long bones from articular cartilage, costal cartilages at the ventral ends of the ribs. It helps to form the nose, larynx, trachea, bronchi and bronchial tubes leading to the lungs.  
  
Fibrocartilage (fibrous cartilage) carries thick dense bundles of white collagen fibres in matrix. They are the strongest cartilage. They occur in joints between vertebrae and also pubic symphysis.  
  
Tendon is a very dense, strong fibrous connective tissue made of collagen fibres. Tendon connects a skeletal muscle to a bone.
7. (a) It is originally hyaline but later become calcified due to deposition of calcium salts in the matrix.
8. (c) It has thick collagen fibres which provide strength, rigidity and firmness.
9. (a) The chondrocytes secrete the flexible matrix called chondrin.
10. (d) Cartilage is a type of connective tissue which is present in human external ears and in the nose tip.
11. (b) Bone is surrounded by dense, white fibrous sheath called periosteum.
13. (c) The cells of mature cartilage called chondrocytes, occurs singly or in groups within spaces called lacunae. The chondrocytes secretes the flexible matrix called chondrin.
14. (b) Haversian canals are interconnected by transverse canals known as volkmann's canals
15. (a) The major component of vertebrate bone is calcium phosphate. Other components include calcium carbonate, magnesium phosphate and sodium chloride.
16. (a) Tendon is white fibrous connective tissue which attaches muscle to bone.
17. (b) Intervertebral disc is a white fibrous cartilage

18. (d) In adult, red bone marrow (myeloid tissue) is responsible for producing red blood cells, granular leucocytes and platelets.
21. (b) If a bone is kept in dilute acid (HCl) for few days, it becomes soft and flexible. This is called decalcification of the bone.

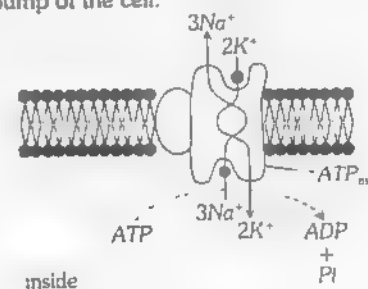
### Vascular tissue

2. (c) The life span of biconcave RBCs in man is 120 days whereas in frog (biconvex RBCs or oval) is 100 days and in rabbit is 80 days.
3. (a) Term leukopenia is applied when, decrease of the number of white blood cells below 5,000 per cubic millimeter
7. (d) Red bone marrow of long bone produces red blood corpuscles, white blood corpuscles and platelets.
8. (b) Camel has oval and nucleated RBCs.
10. (d) Lymph can be defined as blood minus RBCs but more WBCs
15. (b) Because R.B Cs. are isotonic to normal saline solution (0.8% NaCl).
17. (c) Amphibian RBCs are largest amongst the vertebrates. Those of *Amphiuma* and *Proteus* are largest amongst amphibians about  $82\mu m$ . Mammals have smallest RBC's amongst the vertebrates. Those of Musk deer are smallest amongst mammals.
18. (a) Sodium oxalate, sodium citrate and EDTA (Ethylene diamine tetra acetic acid) are used as anticoagulants in blood banks as these bind  $Ca^{++}$  so these are called chelating agent
21. (d) Neutrophils, macrophages and lymphocytes protect the body against foreign microbes by phagocytosis and producing antibodies
22. (d) Haemoglobin is an iron containing respiratory pigment occurring in vertebrate red blood cells and plasma of some invertebrate
23. (c) Radioactive strontium-90 is very much similar to calcium in its chemical behaviour, so it gets deposited in the bone in place of calcium and then damage bone, bone marrow and other organs by continuously throwing out radiations and may also cause tumours and lead to bone cancer.
26. (b) Blood is a fluid connective tissue, which consist of blood corpuscles (RBCs, WBCs and Platelets) and plasma
27. (b) Because of low oxygen demand.
34. (b) Reticulocyte stage is one phase of development of RBCs in which RBCs becomes immature
35. (c) Phagocytosis, the process of engulfing of object (living or dead) by another organism was first discovered by *Metchnikoff*. He also gave the term phagocytosis
36. (c) Iron containing pigment haemoglobin is present in RBC.
38. (a) Neutrophils are about 62% of the total number of white cells so most abundant sub type.
39. (c) Monocytes are the largest corpuscles and phagocytic.
40. (a) Liver produces an anticoagulant, hetero-polysaccharide called heparin which prevent clotting inside the blood vessels
41. (a) Antibodies are produced by a sub population of white blood cells in the immune system called lymphocyte.
43. (a) Agranulocytes are leucocytes that lack granules in the cytoplasm. Since lymphocyte does not have granules in their cytoplasm, so it is called agranulocyte.
44. (a) The life span of the granulocytes once released from the bone marrow is normally 4-8 hours circulating in the blood and another 4 to 5 days in the tissue. The monocyte also have a short life span of 10 to 20 hours. The lymphocytes have life spans of few days or months or even years, but this depends on the body's need for these cells.
45. (b) Monocytes and lymphocytes are agranulocytes.
46. (a) Protein buffers in blood include haemoglobin and plasma proteins. Buffering is done by the imidazole group of the histidine residues. Haemoglobin is quantitatively about 6 times more important than the plasma proteins as it is present in about twice the concentration and contains about 3 times the number of histidine residues per molecule.
48. (c) The chief difference between RBCs of human and frog is that the human RBCs are without nucleus and therefore is not a complete cell. However the absence of nucleus in mammals increases respiratory efficiency of RBCs.
52. (b) Lymphocytes are non-phagocytic. They secrete antibodies to destroy microbes & their toxins, reject grafts & kill tumor cells.
54. (c) Serum is watery fluid left after the clotting of blood. Fibrinogen and corpuscles are absent in serum.
59. (b) Antiserum contains antibodies for a specific antigen. This may be of human or animal origin.
61. (d) Because the conversion of prothrombin to thrombin depends on the action of thromboplastin and calcium.
64. (c) We know that lymph glands are also called lymph node. They are composed of lymphatic tissue and give rise to special white blood cells and antibodies. They act as a defence barrier against the spread of infection by engulfing bacteria and other foreign materials from the lymph. They are not concerned with the formation of RBC.
67. (b) Because there is no antibodies found in serum.
72. (b) During blood coagulation, the intrinsic factor - X activator complex is formed by Activated Christmas Factor (IX) + Antihaemophilic Globulin (AHG) + Phospholipid +  $Ca^{2+}$ .
76. (a) People going to hilly areas will have polycythemia (more number of RBC in blood) after six months and their Hb has a lower binding affinity to  $O_2$ .
79. (b) Heparin is normally secreted by the mast cells of liver.
81. (b) The most important factor controlling the rate of red cell production in the oxygen content of the arterial blood, a decrease in oxygen content stimulates erythropoiesis.

83. (c) Eosinophil is a type of white blood cell that has a granular cytoplasm. Its function involves the regulation of allergic responses and it also produces an enzyme capable of destroying parasites.
84. (c) The total number of WBC in 1 ml is 8000 and number of RBC is 5 millions in 1 ml
87. (a) pH of blood is 7.4 which is slightly alkaline.
90. (a) Thrombus is a clot formed inside the blood vessels. Thrombus is formed due to slowing of circulation and damage of the vascular endothelium.
91. (c) When air with low oxygen tension (anaemia) is breathed for some length of time, the cell count rises due to liberation of erythropoietin or haemopoietin or erythrocyte stimulating factor (ESF).
94. (b) pH of plasma is 7.4 which is slightly alkaline.
98. (c) Yellow substance oozing out of wound is in fact pus which consists of WBC, lymph and dead cells.
104. (c) RBC absorbs  $O_2$  to form oxyhaemoglobin.
106. (d) Since at high altitudes partial pressure of oxygen in air is less, so to facilitate the rapid gaseous exchange; heart rate, respiratory rate, vital capacity, total lung capacity, RBC count and haemoglobin percentage of persons living there increases.
107. (a) Blood corpuscle counting is done by this instrument.
108. (c) Potassium and sodium citrate remove the calcium ions from blood plasma.
121. (a) Fibrinogen is a plasma protein involved in clotting of blood
122. (a) Though, except metabolism rest three options are correct. Yet only statement D is related to their function
10. (d) Sliding filament theory of muscle contraction was given by H.E. Huxley and A.F. Huxley.
14. (b) A striped muscle fibre has many nuclei and it is a syncytium (coenocyte).
16. (a) The sarcoplasm also contains a protein pigment myoglobin, which can take up store or give up oxygen like haemoglobin.
18. (c) Cardiac muscles can contract without the stimulation of nerves and they contract rhythmically.
21. (b) Because there are about 639 muscles which constitutes the bulk of body, 40% of total weight and 50% of soft parts.
23. (c) Due to long refractory period
25. (b) Striated muscles (voluntary muscles) are mostly attached to bones through tendons. The muscles are most abundant in limbs.
26. (c) Ciliary muscles by their contraction exerts tension over the zonule, the ligament which suspends the lens and stretch or relax the lens capsule. The lens has elasticity and hence change of tension on it changes the focal length of lens.
27. (c) During active work, the rate of oxygen supply by the lungs falls short of requirement of the muscles. Hence, lactic acid accumulates in the muscles and the breathing gradually becomes hard to enhance  $O_2$  intake by the lungs. This is called oxygen debt.
29. (a) Energy from ATP cause conformational change in the solute carrier complex. From energy of one ATP,  $3Na^+$  are pumped outside and two  $K^+$  are taken in. This process of expelling out  $Na^+$  ions and drawing in  $K^+$  ions against the concentration gradient and electrochemical gradient is called sodium-potassium exchange pump of the cell.

### Muscular tissue

1. (c)  $Ca^{++}$  is a essential element for the contraction of muscles because release of  $Ca^{++}$  ions from sarcoplasmic reticulum trigger the muscle contraction process
2. (c) Troponin is a protein which is found on Actin filament and myosin protein is found in myosin filament. Both Actin and Myosin are complex proteins in striated muscles
3. (c) Involuntary action of striated muscles yield some heat to warm the body.
4. (b) Unstriated muscles are the most widely distributed muscles in the body, e.g., Gastrointestinal tract, uterus, Urinary bladder, iris, ciliary body, blood vessels etc.
5. (c) Cardiac muscles have a mixture of properties of both striated and unstriated muscles. These muscles continue rhythmic contraction throughout life under the control of ANS.
7. (b) The plasma membrane covering the muscle fibre is called sarcolemma.
8. (b) Sliding filament theory tells that actin slides over myosin during contraction where the length of I-band and sarcomere reduces but no change in length of any filament
9. (c) Myocardial layer contains cardiac muscles.



This pump operates by involving the  $Na^+ - K^+ - ATPase$  enzyme located in the cell membrane. Such electrogenic pump develops positive charge outside the membrane and negative charge to cell's interior. This difference in charge on either side of the membrane of a resting neuron is the resting membrane potential.

31. (a) One thin filament probably contains 300-400 actin molecules about 50 tropomyosin and 50 troponin. It is said that tropomyosin plays a vital role in sensitizing the contractile proteins (actin and myosin) to calcium ions
35. (b) Actin and myosin are related with muscle contraction. In muscle contraction, overlapping of actin and myosin molecules interact to form actomyosin complex.

36. (a) Muscles have their own oxygen-carrying iron-protein pigment myoglobin or muscle haemoglobin.
38. (b) The distance between two Z-lines is called as sarcomere which is a functional unit of the muscle. Each sarcomere includes one complete A-band and 2 halves I-bands on the sides ( $1/2 + A + 1/2$ ).
39. (b) Increase in the size of an organ because of enlarged cells is called hypertrophy.
41. (d) Gluteus maximus is the largest muscle. It is present in the buttock and extends and rotates the thigh laterally.
43. (b) The immediate energy source for muscle contraction is ATP which is present only in small quantities at any given time in the muscle.
48. (a) During muscle contraction, ATP undergoes hydrolysis in the presence of water and myosin ATP are to form ADP + Pi and liberation of energy.
50. (a) Cardiac muscles form the walls of heart. These are intermediate in structure being striated and involuntary. It is meant for automatic and rhythmic contraction. On the other hand skeletal muscles are striated and voluntary, they are most abundant and found attached to skeleton. They are supplied by somatic nerve and hence are under voluntary control.

### Nervous tissue

1. (d) Multipolar neurons have several dendrites and one axon. Most neurons in the brain and spinal cord of our body are of this type
3. (a) Schwann cells are specialised glial cells that form the myelin sheath that coats axons. In peripheral nerve fibre the myelin sheath is interrupted at regular intervals; these interruptions constitute the node of Ranvier.
4. (c) Neurons are structural and functional units of nerve tissue. Their number is quite high, more than  $1 \times 10^{12}$  in brain alone
7. (b) Nervous tissue consists of cells having a well developed power of irritability and conductivity, forms nervous system.
8. (a) The whole nervous system originates from the ectoderm.
10. (d) Nerve fibres are extended axons or dendrites. Dendrites carry nerve impulses toward the cell body and axon away from it.
13. (a) Neurons are of two types on the basis of axon length, Golgi type-I and Golgi type-II. In Golgi type-I, neuron possess very long axons.
15. (b) Two type of brain cells are found : The neuron and neuroglia. Neurons are functional typical nerve cells which generate and conduct impulses. Due to high degree of specialization the neuron lose their ability to divide. The neuroglia are with ability of division.
16. (c) Non-excitable, supporting components of the nervous tissue include neuroglial cells and schwann's cells.
18. (b) Myelin sheath is a layer covering of vertebrates nerve fibre
19. (b) Schwann's cell secrete a segment of myelinated fibre called internode.
22. (d) Nissl granules or Nissl bodies are basophilic structure of various shapes-angular, conical or rhomboidal. They are pieces of granular endoplasmic reticulum with or without free polyribosomes. They are found in cytons.
23. (b) Because dendrite receives the impulse for neuron.
28. (a) If a nerve impulse was initiated somewhere in the middle of a nerve fibre, it would proceed to both ends. However, in the synapse, the propagation is strictly one-way from the axon to the dendrite never the reverse.

### Critical Thinking Questions

4. (b) Inner lining of cheeks have compound stratified squamous epithelium.
6. (c) Epidermis has several distinct layers of epithelial cells. The innermost layer called stratum germinativum has columnar cells resting upon a common basement membrane.
10. (c) Canaliculi are the protoplasmic processes between osteocytes.
11. (b) Connective tissues function in binding together and constitute the framework of many organs. Collagen is a protein of connective tissue that combine to form the tendons and ligaments.
12. (c) Brown fat contains fat cells with several small fat globules. Brown colour is due to iron-containing cytochrome pigment in fat.
13. (a) Moist surface of buccal cavity – Stratified non-keratinised squamous epithelium  
Inner surface of bronchioles – Ciliated epithelium  
Inner lining of salivary ducts – Cuboidal epithelium.
18. (c) Nucleus of granulocytes is irregular and divided into 2-5 interconnected lobes. Hence these are also called polymorphonuclear leucocytes
20. (b) Main haemopoietic organ in embryonic stage is liver. Other haemopoietic organ during foetal life – yolk sac, spleen, lymphnodes, red bone marrow
21. (c) During blood clotting injured tissue or platelets release a lipoprotein factor called thromboplastin. Thromboplastin helps in the formation of the enzyme thrombokinas
22. (b) Lymph has no RBCs but about 99% are lymphocytes usually of the small type, the remaining 1% is made up of leucocytes.
23. (c) All fasciculi of a muscle are bound together by a connective tissue termed perimysium which also forms a sheath around each fascicule
24. (a) Each resting cell is in a polarized across its membrane called resting membrane potential. This potential averages – 70 mv (– 60 to – 90 mv) on inner side of the membrane in respect to its outer side
25. (a) Biceps and triceps work as antagonistic muscles at elbow. Contraction of biceps and relaxation of triceps causes flexion of arm. Similarly, contraction of triceps causes extension of arm at elbow.

## Assertion and Reason

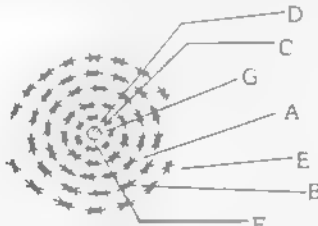
1. (d) Total count of RBC refers to the total number of red blood corpuscles (erythrocytes) present in one microlitre of the blood. It average 5 million and 4.5 million in adult man and woman respectively. Total count of RBC comes out to be very low in condition of anaemia and after profuse bleeding. On the contrary, polycythemia is the condition which arises due to the abnormal rise in the total count of RBC.
2. (c) Conjugated proteins are the proteins which are formed by the binding of a simple protein with a non-protein prosthetic group. Conjugated chromoproteins are the pigment protein complexes. Haemoglobin is one such conjugated chromoprotein. It is composed of a simple protein called "globin" and non protein iron ( $\text{Fe}^{2+}$ ) porphyrin complex called "heme". 100 ml of blood contains about 15g of haemoglobin. Four  $\text{Fe}^{2+}$  ions of heme can loosely bound to upto four molecules of oxygen, thus enabling haemoglobin to carry oxygen.
3. (a) Histamine is a derivative of the amino acid histidine produced by damaged cells of vertebrates. When released, It has the effect of dilating capillaries and lowering blood pressure. Histamine is involved in allergic and inflammatory reactions.
4. (e) Treating the blood to low temperatures (chilling) decreases the activity of coagulation promoting enzymes. So, at low temperatures it will take more time for the blood to clot i.e. the coagulation of blood gets delayed. Thus chilling of blood increases the coagulation time (time taken for the blood to coagulate) and not decrease it
5. (c) Blood coagulation is brought about by the hydrolysis of soluble protein fibrinogen to insoluble fibrin. This reaction is catalysed by the enzyme thrombin. Thrombin occurs in normal blood as an inactive globulin called prothrombin which is activated to thrombin by the action of another enzyme called prothrombinase before blood coagulation starts. Thromboplastins are the coagulation promoting substances released from clumped platelets and damaged tissue, which helps in the formation of the enzyme prothrombinase.
6. (a) The symptoms of an allergic reaction develop in response to histamine. Mast cells release a large amount of histamine into the blood stream and it also act as initiator of the inflammatory response which aids the arrival of leucocytes at a site of infection. Histamine stimulates capillary dilation, increased capillary permeability, closure of bronchial tubes, mucus secretion, pain and swelling.
7. (e) Regulation of RBCs production is accomplished by hormone erythropoietin which is secreted by kidney. This hormone increases stem cell mitosis and speed up RBC's development in red bone marrow.
8. (e) Since muscle cells are very thin and elongated, therefore, they are also called as muscle fibres and not myofibril. Myofibril is the unit of a striated muscle fibre. A striated muscle fibre is composed of many myofibrils arranged along the long axis of the fibre. A myofibril is of two types of myofilaments-actin filaments and myosin filaments. Sliding of these myofilaments over one another cause the contraction and relaxation of the muscle fibre.
9. (b) The thigh muscles are the striated muscles which soon get fatigued due to overwork. These muscles show fast contractions and then tire immediately due to accumulation of lactic acid. The muscles of heart wall are the cardiac muscles which are unfatiguable and show rhythmic and automatic contractions. They have specialised regions of the cell membranes which function as boosters for muscle contraction waves. Thigh muscles are called voluntary muscles because they can be moved at the will of organism whereas heart muscles can't be moved at one's will and therefore are involuntary.
10. (b) In wounds, germs are removed by WBCs accumulation at wound site by diapedesis. It is squeezing of leucocytes out from endothelium of capillaries to fight external agent.
11. (d) Non striated or smooth muscles are said to be involuntary in nature because they do not contract or relax according to our will. Those muscles which can be moved according to will of the organism are called voluntary muscles. Striated or skeletal muscles are said to be voluntary in nature as they can be contracted or relaxed voluntarily
12. (a) Cardiac muscle cells are short cylindrical cells joined end to end and by side branching to form a network. Intercalated discs are the dense junctions formed in between the cardiac muscle cells where they meet each other. Intercalated discs are the specialised regions of the cell membranes. As cardiac muscle possesses considerable rhythmicity and generates its own wave of excitation, these discs function as boosters for muscle contraction wave
13. (d) Ordinary connective tissue is absent inside the central nervous system. i.e. brain and spinal cord and has no function in the conduction of nerve impulse. The neurons of nerve tissue inside the brain and spinal cord are held together by supporting cells called neuroglia cells. Neuroglia cells resemble neurons and have long radiating processes but no nissl granules.



14. (a) Histamines are involved in allergic and inflammatory reactions. Histamines also dilate capillaries.
15. (c) Myelin sheath is a lipid rich insulating layer which covers some nerve fibres of nerve tissue. Such fibres are called myelinated or medullated nerve fibres. Each myelinated nerve fibre shows constrictions at regular intervals called nodes of Ranvier which results from interruption in the myelin sheath at those places. Non myelinated nerve fibres are not covered by any myelin sheath, consequently no nodes of Ranvier are present in them.
16. (a) Specialization of cells into tissue, organ and organ systems is advantageous for the organism. It increase the operational efficiency through division of labour which avoids duplication of work.
17. (b) Cartilage comprises of mucopolysaccharide called chondroitin sulphate. Bone is a hard connective tissue. Blood is a fluid connective tissue.
18. (e) Though blood vessels are absent in epithelial tissues, exchanges of materials takes place in them. Materials are exchanged between epithelial cells and vessels of the connective tissues by diffusion across the basement membrane. Also through osmosis and filtration, epithelial tissues exchange materials (e.g. epithelial tissues of pulmonary vein, Bowman's capsule etc).
19. (a) The columnar epithelium bearing microvilli on their free ends give a brush-like appearance to these free border. Villus shaped microvilli greatly increase the area of the free surface of the cell and thereby enhance absorption. Lining of gall bladder, stomach, large intestine are the example of columnar epithelium.
20. (e) Fatigue is the inability of a muscle to contract. It is due to depletion of its chemicals and lactic acid accumulation by repeated contraction.
21. (a) Fibroblasts are the principal cells of areolar tissue. Fibroblasts synthesize two kinds of proteins-collagen and elastin. The tensile strength of collagen fibres and the elasticity fibres prevent displacement and injury of tissues and organs under mechanical stress. Collagen fibres are also laid down at sites of injury and help in tissue repair.
22. (d) Lacunae are actually the flat irregular spaces occurring in the solid matrix of bone. Each lacuna lodges a flat bone cell or osteocyte. Compact bone possesses many parallel, longitudinal column like structures called haversian systems, in which several concentric layers of bony matrix called lamellae encircle a longitudinal central canal called haversian canal. It is the Haversian canal, which carries blood vessels and nerves to the bone. Lacunae containing osteocytes occur in a layer between two lamellae.
23. (e) Keratinised stratified squamous epithelium is a compound epithelium which covers the dry surface of skin. It has many layers of epithelial cells. The deeper layers are formed by living polygonal cells but superficial layers constitute of horny, scale like remains of dead squamous cells. Heavy deposits of the insoluble protein keratin in the dead superficial cells make the epithelium impervious to water and highly resistant to mechanical abrasions.
24. (a) Extracellular materials (also called Intercellular materials) are very important for cells because they surround the individual cells, separate them from each other and bind them together. One or more types of specialized cells are set in specific extracellular materials to constitute a tissue. Nature and amount of extracellular material vary from tissue to tissue. In some tissues, it is limited to very thin layers whereas, in some it is quite vast and separates cells widely apart from one another.
25. (d) Simple epithelium doesn't cover surfaces exposed to mechanical or chemical abrasions, because it is made up of a single layer of cells, hence it is not effective in protecting the underlying tissue. Simple epithelium occurs mainly on secretory and absorptive surfaces. There is another types of epithelial tissue called compound epithelium which being multilayered is effective in providing protection to underlying tissues, hence covers the surfaces exposed to mechanical and chemical abrasions
26. (d) It is not tendon but another type of connective tissue called ligament which is present in most of the bone joints and connect the bones together. Ligament also helps in holding the bones in position. Tendon, on the other hand, is a dense, strong, fibrous connective tissue which forms strong inextensible attachment of a skeletal muscle to a bone.
27. (c) Urinary bladder is not lined by squamous epithelium but by transitional epithelium which is a stretchable compound epithelium. It has a single layer of cuboidal cells at the base, 2-3 middle layers of large polygonal cells and a superficial layer of large, broad rectangular cells. Stretching considerably flattens and broadens the cells of superficial and middle layers, hence causing expansion of the urinary bladder.
28. (b) On the basis of presence of tiny granules and number of lobes in nucleus of their cytoplasm, white blood cells are divided into two groups
  - (i) Granulocytes Contain tiny granules and lobed nuclei in their cytoplasm.
  - (ii) Agranulocytes Have no cytoplasmic granules in their cytoplasm and their nuclei are also undivided
29. (a) Columnar epithelium is a type of simple epithelium characterised by the presence of tall column like cells. Its major function is absorption or secretion. It covers the inner surface of the intestine, stomach and gall bladder. In the intestine it appears to have a brush like appearance on the free surface, which is due to the presence of large number of microvilli. Function of microvilli is to enhance absorption. Due to the presence of microvilli, the epithelium is also called as brush bordered columnar epithelium.
30. (a) The regulation of RBC production is accompanied by the hormone erythropoietin, which is secreted by the juxtaglomerular cells of kidney. This hormone circulates to the red bone marrow, where it increases stem cell mitosis and speeds the development of RBC

## Animal Tissues

## SET Self Evaluation Test

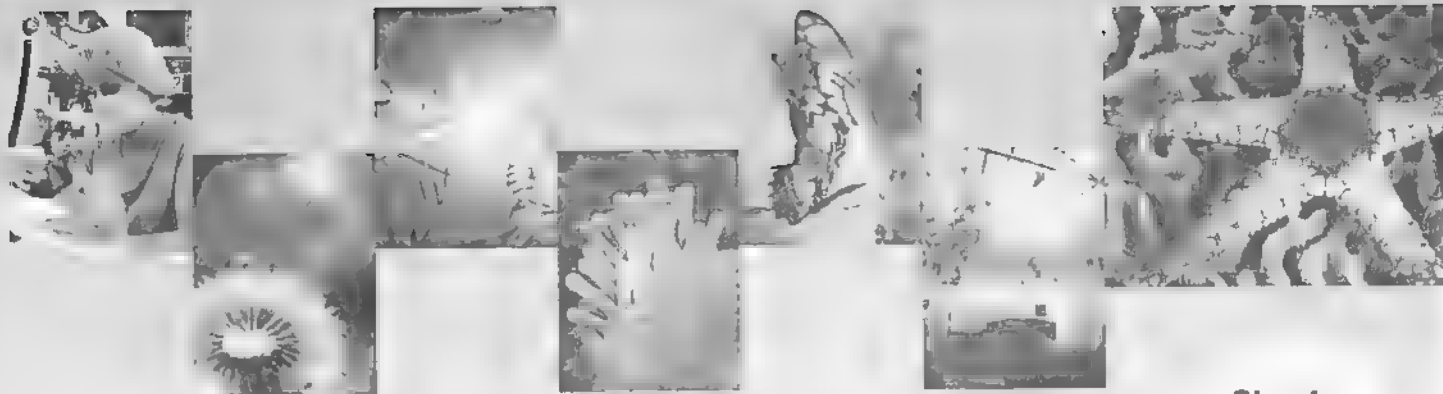
- Which one of the following is wrongly matched  
[Kerala PMT 2009]  
(a) Myosin – Contractile protein  
(b) Tendon – Connective tissue  
(c) Smooth muscle – Involuntary muscle  
(d) Red muscle – Myoglobin  
(e) Troponin – Fibrous protein
- Pseudostratified epithelium is always [DPMT 1993]  
(a) Single layered (b) Double layered  
(c) Multilayered (d) Uncertain
- Find the wrongly matched pair [Kerala PMT 2012]  
(a) Unicellular glandular cells – Goblet cell  
(b) Saliva – Exocrine secretion  
(c) Fusiform fibres – Smooth muscle  
(d) Cartilage – Areolar tissue  
(e) Intercalated discs – Cardiac tissue
- The epithelial lining the alveoli of the frog's lungs facing lung cavity is [BHU 2008]  
(a) Columnar, non-ciliated (b) Columnar, ciliated  
(c) Squamous, ciliated (d) Squamous, non-ciliated
- Epithelial cells adhere to one another with considerable force due to [BHU 2005]  
(a) Intercellular attraction (b) Presence of desmosomes  
(c) Both the above (d) None of the above
- Basement membrane is made up of [CBSE PMT 1997]  
(a) Epidermal cell only  
(b) Endodermal cell  
(c) No cell product of epithelial cell  
(d) Both (a) and (b)
- Transitional epithelium is found in [AFMC 1997]  
(a) Lungs (b) Liver  
(c) Urinary bladder (d) Stomach
- The term "blubber" refers to [KCET 1994]  
(a) A substitute for natural rubber  
(b) A subcutaneous deposition of fat in whales  
(c) The irregular heart-beat sound  
(d) None of these
- Fats are richly found in [NCERT: MP PMT 1994, 2003; Pb. PMT 1999]  
(a) Alveolar tissue (b) Lymph glands  
(c) Adipose tissue (d) Liver cells
- In the diagram of the section of bone tissue given below, certain parts have been indicated by alphabets; choose the answer in which these alphabets have been correctly matched with the parts which they indicate [KCET 2001]  
  
(a) A = Interstitial lamellae, B = Lacuna with osteocytes, C = Blood vessels, D = Nerve, E = Canaliculi, F = Haversian canal, G = Lamellae  
(b) A = Interstitial lamellae, B = Osteocytes in the lacuna C = Blood vessels, D = Nerve, E = Lamellae, F = Haversian system, G = Canaliculi  
(c) A = Lamellae, B = Lacuna with osteocytes, C = Artery, D = Lymphatic vessels, E = Canaliculi, F = Vein, G = Haversian canal  
(d) A = Interstitial lamellae, B = Osteocytes, C = Nerve, D = Blood vessel, E = Lamellae, F = Haversian canal, G = Canaliculi
- Vertebrate nails are derivatives of [MP PMT 2013]  
(a) Stratum lucidum (b) Stratum germinatum  
(c) Stratum granulosum (d) Stratum corneum
- Shivering in cold is a method for [MP PMT 2001]  
(a) Prevention of radiation of heat from the body  
(b) Production of healthy muscle friction  
(c) Production of heat by muscular contractions  
(d) Increasing blood supply to skin
- A tendon gets ossified to form a type of bone called [MP PMT 2002]  
(a) Sesamoid (b) Membranous  
(c) Dermal (d) Cartilage
- With the help of the given variables, identify the correct sequence, that leads to the formation of blood clot [EAMCET 2009]  
(A) Blood clot (B) Injury  
(C) Factor II (D) Factor III  
(E) Factor IV (F) Fibrinogen  
(G) Thrombin  
(a)  $B \rightarrow C \rightarrow D \rightarrow F \rightarrow G \rightarrow A$   
(b)  $B \rightarrow C \rightarrow G \rightarrow F \rightarrow A$   
 $\quad \quad \quad \uparrow \quad \uparrow$   
 $\quad \quad \quad D \quad E$   
(c)  $D \rightarrow B \rightarrow C \rightarrow G \rightarrow F \rightarrow A$   
 $\quad \quad \quad \uparrow \quad \uparrow$   
 $\quad \quad \quad D \quad E$   
(d)  $B \rightarrow D \rightarrow C \rightarrow F \rightarrow G \rightarrow A$   
 $\quad \quad \quad \uparrow \quad \uparrow$   
 $\quad \quad \quad D \quad E$

- ## Answers and Solutions

1	e	2	a	3	d	4	b	5	b
6	c	7	c	8	b	9	c	10	c
11	d	12	c	13	a	14	b	15	d
16	d	17	d	18	b	19	b	20	d
21	d	22	c	23	a	24	d	25	c
26	d	27	c	28	b				

2. (a) The pseudostratified epithelium without being truly stratified appears to have 2 or 3 layers of cells as nuclei are present at two levels but actually it is single layered
6. (c) Basement membrane is a delicate intercellular membrane visible in light microscope, which underlies most animal epithelia. Besides this, the basal lamina consists of mucopolysaccharide and very fine fibres.
7. (c) Transitional epithelium is thin flexible and impermeable to water. It forms the inner layer of urinary bladder.
8. (b) Blubber is thick subcutaneous fat insulating body heat in aquatic mammals like whales.
9. (c) The fat storage tissue is called adipose tissue, it is a connective tissue. It also forms shock proof cushions around the kidney, ovaries and eye ball
12. (c) "Shivering with cold" in winter is caused by a quick involuntary reaction of striated muscles. It yields, not a mechanical work but only some heat just to warm the body
13. (a) Sesamoid bone is formed by the ossification of tendons e.g. patella.
14. (b) 
$$\begin{array}{ccccc} \text{Injury} & \longrightarrow & \text{Prothrombin} & \longrightarrow & \text{Thrombin} \\ & & \uparrow & & \downarrow \\ & & \text{Thromboplastin} & \xleftarrow{\text{Ca}^{2+} \text{ ions}} & \text{Fibrinogen} \longrightarrow \end{array}$$

Thrombin  $\longrightarrow$  Blood clot  
So, option (b) is correct.
16. (d) Due to the absence of nucleus, mammalian R.B.Cs become biconcave shape which help to accommodate maximum amount of haemoglobin
17. (d) Muscles of the gut wall are innervated by autonomic nerve fibres and are self-excitatory.
18. (b) Plasma is extracellular fluid.  $\text{Na}^+$  is the principal mineral cation in the extracellular fluid
20. (d) Cardiac muscles have mixture of properties of both striated and unstriated muscles. These muscles continue rhythmic contraction throughout life under the control of A.N.S.
23. (a) A striped muscle fibre has many nuclei and it is a syncytium (coenocyte).
25. (c) Monocyte is the largest white blood cells (WBCs) whereas haemoglobin is found in R.B.Cs. Thus monocyte is not correctly matched with haemoglobin.



## Chapter

# 2.4

## Morphology of Animals

### ***RANA TIGRINA* (The Common Indian Frog)**

#### **Systematic position**

Phylum	–	Chordata
Sub phylum	–	Vertebrata or Craniata
Class	–	Amphibia
Order	–	Salientia or Anura
Genus	–	<i>Rana</i>
Species	–	<i>tigrina</i>

#### **Habitat**

*Rana tigrina* is the most widely distributed species in Northern India. Generally frogs are found in ponds, tank, pools, ditches, etc. However, they may leave their aquatic habitat to come on land to hunt for their prey, which are mostly insects.

#### **Habits**

(1) **Locomotion** : (a) Jumping and leaping, (b) Swimming. Absence of neck is helpful in swimming in water and jumping on land

(2) **Feeding** : The adult frog is carnivorous. Tadpole (larva of frog) is herbivorous.

(3) **Croaking** : The male frog croaks louder than the females because of the presence of two vocal sacs in male frog. The vocal sacs act as resonators. The croaking is mating call to attract the female frog.

(4) **Hibernation (Winter sleep)** : During hibernation frog respire through skin (cutaneous respiration) only

(5) **Aestivation (Summer sleep)** : During this period frog takes rest in shady, cool and moist place and recuperates its energy

(6) **Protective Colouration** : The frog is capable of changing its body colour with change in its surroundings. It can not only avoid its enemies but can catch its prey unnoticed

(7) **Breeding** : The male frog jumps on the female frog and holds her tightly with the help of his fore-limbs. Gripping of the female by the male is also very much aided by the presence of nuptial pads. This sexual embrace is called the amplexus. Fertilization is external. During development, a fish like tailed tadpole is produced, which respire with the help of gills and feeds upon vegetable matter.

(8) **Moulting** : The frog sheds off almost once a month its skin during its active life in the form of small casting. This phenomenon is known as moulting or ecdysis

#### **External morphology**

The dorsal surface of frog is spotted olive green and ventral pale yellow, this protective colouration help to camouflage, i.e. escape the detection by enemies

**Body division** : The body of frog has two main divisions head and trunk; absence of neck and tail helps both in jumping on land and swimming in water

(1) **Head** : Head is anterior flattened triangular part with, a wide transverse terminal mouth, a pair of small dorsal external nares, two dorso-lateral eyes, a mid-dorsal light coloured brow spot or third eye or pineal body and obliquely placed pigmented circular tympanum or ear drum. Eyes are provided with nictitating membrane for protection

(2) **Trunk** : Trunk is the large, oval, flattened main part of the body. It is differentiated into hard anterior thorax and soft posterior abdomen. The trunk is provided with a pair of fore and hind limbs. The fore limbs are shorter and stouter, end in four digits thumb or pollex is absent. The hind limbs are much larger and muscular than the fore limbs, end in five digits.

### Sexual dimorphism

The male and female frogs can be differentiated externally. The male frog possesses vocal sacs, which are most developed during the breeding season. During the breeding season an amplexusory or nuptial pad is developed on first finger of each hand of the male frog.

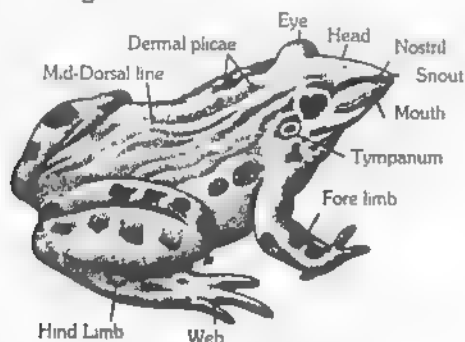


Fig : 2.4-1 External morphology of frog

### Internal morphology

#### Skin (Integument)

Histologically, the skin consists of outer epidermis and inner dermis.

(1) **Epidermis** : Epidermis is ectodermal in origin and is made up of stratified squamous epithelium. It consists of stratum germinativum (*S. malpighi*), *S. spinosum*, *S. granulosum*, *S. lucidum* and *S. corneum* (horny layer). *S. corneum* is protective in function and is periodically cast off (moulting). This phenomenon, is known as ecdysis.

(2) **Dermis** : It is punctured at places by ducts of cutaneous glands. Dermis is region of skin that lies below the epidermis. It has a loose connective tissue or stratum spongiosum on the outside and compact dense connective tissue or stratum compactum on the inner side. Stratum spongiosum has lymph spaces, nerve fibres, blood capillaries, mucous glands, poison glands, and chromatophores. Mucous glands secrete mucus which makes the skin moist and slippery. Chromatophores provide colouration to skin. They are of three types-melanophores (brownish black), lipophores (reddish and yellowish) and guanophores (whitish).

#### Digestive system

It consists of alimentary canal and digestive glands.

**Alimentary canal** : The alimentary canal of frog is a long and coiled tube with varying diameter extending between mouth and cloaca.

(1) **Mouth** : The mouth is a terminal wide opening bounded by two bony jaws. Upper jaw is fixed while lower jaw can move up and down with the help of hinge joint.

(2) **Buccopharyngeal cavity** : Teeth are present on premaxillae, maxillae of upper jaw and vomers of the roof of buccopharyngeal cavity. The lower jaw of frog is toothless. Teeth are homodont, acrodont and polyphyodont. These are not used for chewing instead they help to hold the prey. The tongue is large muscular, sticky, bilobed at the tip and free from behind and is used for capturing the prey. Frog has no salivary glands. Various apertures like opening of eustachian tube, vocal sac (only in male), gullet and glottis are present in the buccopharyngeal cavity.

(3) **Oesophagus** : Because of the absence of neck in frog, the oesophagus is only a short tube. The oesophagus leads to the stomach.

(4) **Stomach** : It is divisible into two parts. Cardiac stomach, the anterior larger part is present near the heart. The opening of the oesophagus into the cardiac stomach is guarded by a cardiac sphincter, a powerful narrow tapering part, which is separated from the duodenum by a muscular constriction, the pyloric constriction externally, which indicates the position of pyloric sphincter, which controls the entry of food into duodenum.

(5) **Small Intestine** : It is the longest part of the alimentary canal suspended by mesentery, and is divisible into duodenum and ileum.

(i) **Duodenum** : It is a 'U' shaped structure. It receives the hepatopancreatic duct from the liver and pancreas.

(ii) **Ileum** : It is a narrow tube which is coiled in order to accommodate itself in a limited space. The internal lining of the ileum is thrown into a large number of finger like branched projections known as villi which increases the absorptive surface area.

(6) **Rectum (Large Intestine)** : Posteriorly, it opens into the cloaca through an aperture known as anus which is guarded by an anal-sphincter. The rectum stores the faecal matter and water is absorbed by its wall.

(7) **Cloaca** : It is the last part of the alimentary canal, which receives the rectum in both the sexes, but in female frog, the cloaca also receives the ureters and oviducts, while in the male the urinogenital ducts are received in addition to the rectum.

The urinary bladder also opens into the cloaca. The cloaca opens out through a cloacal aperture.

#### Digestive glands

(1) **Liver** : It is the largest gland of the body. It consists of three lobes-right, left and median. Liver secretes a greenish alkaline fluid bile, which is temporarily stored in gall bladder before being released into the duodenum. Bile helps in digestion of food by changing its pH from acidic to alkaline and by emulsifying the fat.

(2) **Pancreas** : It is diffused creamish gland that lies in the loop between stomach and duodenum. It has lobules that secrete pancreatic juice. Pancreatic juice is alkaline. It contains amylolytic, proteolytic and lipolytic enzymes. Pancreatic juice is poured alongwith bile into duodenum through hepatopancreatic duct.

(3) **Gastric Glands** : They secrete gastric juice having HCl and pepsinogen. Oesophagus also has glands which produce propepsin. Both propepsin and pepsinogen are changed into active pepsin.

(4) **Intestinal Glands** : Their secretion is called intestinal juice or succus entericus. It contains enzymes peptidases, maltase, lipase, etc.

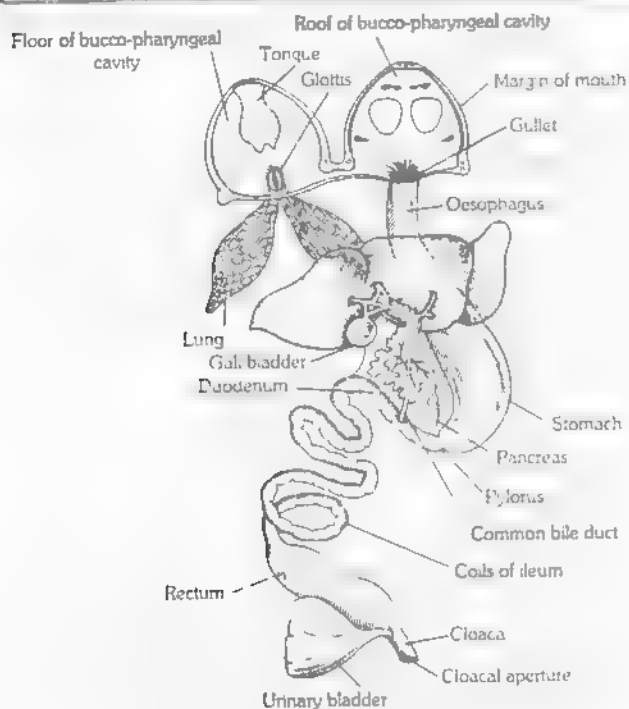


Fig : 2.4-2 The digestive system of frog

### Respiratory system

Frog can perform respiration through three methods- cutaneous, buccopharyngeal and pulmonary

(1) **Cutaneous Respiration** : Skin of Frog is thin and richly supplied with blood capillaries. It is kept moist by mucus and water. Oxygen from air diffuses into blood through moisture over the skin.  $\text{CO}_2$  similarly, diffuses in the reverse direction from blood to air through moist surface of skin. Cutaneous respiration occurs in water, during hibernation and even aestivation. So it is the most vital mode of respiration.

(2) **Buccopharyngeal Respiration** : Exchange of gases take place in the lining layer of buccopharyngeal cavity. Throat is raised and lowered alternately by petrohial and sternohial muscles respectively. This expels out foul air and brings in fresh air. Buccopharyngeal respiration is performed when oxygen requirement is less, during rest over land and while 'floating' in water.

(3) **Pulmonary Respiration** : It occurs when oxygen demand is high. The rate is not more than 20/min. as compared to 80/min for buccopharyngeal respiration. Throat is lowered, air from outside enters buccopharyngeal cavity, it is called aspiration. Throat is raised, glottis opens and air passes into lungs through laryngotracheal chamber, it is called inspiration. Lungs are two ovoid pinkish elastic bags having a large number of small shallow chambers or alveoli. Blood capillaries overlie the epithelial lining of the alveoli. Exchange of gases occurs between air and blood capillaries. Lungs contract and foul air is pushed into buccopharyngeal cavity by lowering of throat. Throat is now raised, external nares opened and the foul air is passed out. The process is called expiration.

### Laryngotracheal chamber

It is voice box of frog. Laryngotracheal chamber possesses two vocal cords, an opening of glottis into pharynx and bronchus

into lungs. It is supported by three cartilages, two arytenoid and one cricoid

### Circulatory system

The circulatory system of frog consists of blood vascular system and lymphatic system

(1) **Blood Vascular system** : It is of closed type as the blood flows in the blood vessels. It represents single circulation. It means both the oxygenated and the deoxygenated blood enters the heart and get mixed in the ventricle. Blood vascular system comprises blood, heart and blood vessels.

(i) **Blood** : It is mobile connective tissue consisting of blood plasma (fluid) and blood corpuscles (cells). Three types of blood corpuscles are present in the plasma, viz, erythrocytes (RBCs-Red blood corpuscles), leucocytes (WBCs-white blood corpuscles) and thrombocytes-spindle cells. RBCs are nucleated, oval and biconvex and have haemoglobin (respiratory pigment). WBCs are amoeboid shaped and are protective in function. Thrombocytes are spindle shaped and help in blood clotting.

(ii) **Heart** : The heart lies enclosed by a thin, transparent, two layered sac, pericardium. It is a three-chambered structure made of two upper auricles and a single lower ventricle. Two additional chambers connected to the heart of frog are sinus venosus and truncus arteriosus. Sinus venosus is a triangular chamber attached dorsally to heart formed by the union of three main vena cava. A short sac like truncus arteriosus is present on the ventral side of the heart over the larger right auricle. Truncus arteriosus is further divided into a long basal thick walled conus arteriosus or pylangium and a short distal thin walled bulbous aorta or syngangium. A large twisted spiral valve further divides incompletely the cavity of pylangium into a left dorsal cavum pulmocutaneum and right ventral cavum aorticum. A definitely arranged network of arteries and veins forms the arterial and venous systems.

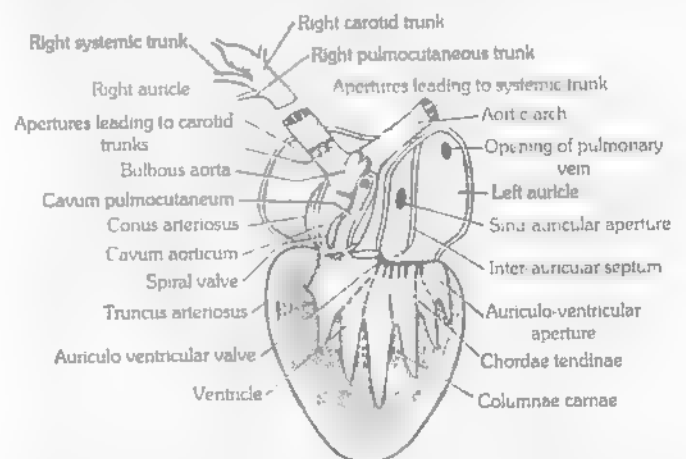


Fig : 2.4-3 Heart of frog

(2) **Portal system** : In some vertebrates there is a characteristic arrangement where the veins does not directly take blood towards the heart but divides into a capillary set and supply the organ. This is known as portal system. In frog there are two portal systems -

- (i) Renal portal system
- (ii) Hepatic portal system

**Portal System :**

(i) **Renal Portal System** : A branch from femoral called femororenal combine with sciatic vein to form renal portal vein. It proceeds towards kidney of its side, receives a dorso-lumbar and then enters the kidneys breaking up into capillaries for quicker extraction of nitrogenous waste products and salt. The purified blood is then collected from the kidney by renal veins

(ii) **Hepatic Portal System** : It is formed of two veins, hepatic portal vein and anterior abdominal vein. Hepatic portal vein is formed by fusion of a number of veins from digestive tract-rectal, intestinal, splenic, duodenopancreatic, gastric and oesophageal. Anterior abdominal is formed by the union of pelvic branches from femorals. It receives vesicular vein from urinary bladder and a number of small veins from abdominal wall. Near liver it is joined to hepatic portal vein by a small branch. The two then enter liver, break up into capillaries for disposal of their contents. Purified blood is taken out by hepatic veins into postcaval.

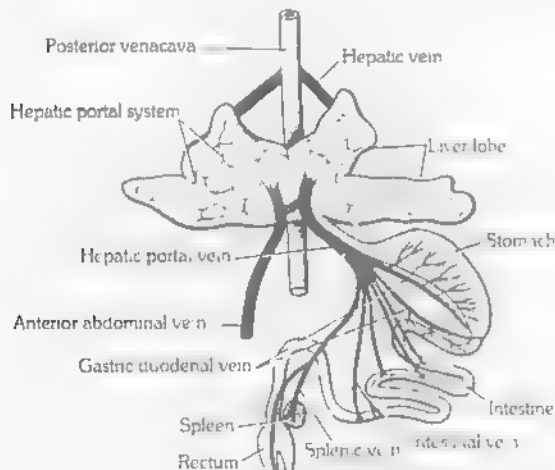


Fig : 2.4-4 Portal system of frog

(3) **Lymphatic system** : Lymph flows through the lymphatic system. Lymph is like blood but it is without RBCs and thrombocytes. It is colourless. Lymph acts as "middle man". In addition to the lymph, lymphatic system comprises lymph capillaries, (closed at the tip), lymph sinuses (spaces filled with lymph) and two pairs of lymph hearts. The flow of lymph is from the lymph capillaries → lymph sinuses → lymph hearts → veins

**Nervous system**

The nervous system of frog is composed of central nervous system, peripheral nervous system and an autonomic nervous system.

(1) **Central nervous system** : It comprises the brain and spinal cord. The brain is lodged in the skull, while spinal cord is enclosed by the vertebral column

(2) **Peripheral nervous system** : The nerves arising from the central nervous system constitute the peripheral nervous system. The nerves originate from the brain and spinal cord and are known as cranial nerves and spinal nerves respectively.

(3) **Autonomic nervous system** : It includes the nerves and ganglia that control and coordinate such organs which are not under voluntary control. It comprises sympathetic nervous system and parasympathetic nervous system.

**Brain** : The brain is the anterior most part of the central nervous system. It is situated in the cranial cavity and is covered by

a delicate, pigmented and vascular membrane, the pia mater. The cranial cavity is internally lined with a tough membrane, the duramater. The space in between duramater and pia mater is filled with a shock absorbing cerebrospinal fluid. The brain is divided into forebrain, midbrain and hindbrain. The forebrain includes olfactory lobes, paired cerebral hemisphere and unpaired diencephalon. The mid brain, the broadest, bears dorsolaterally a pair of large rounded optic lobes (corpora bigemina). The hind brain consists of a poorly developed cerebellum and medulla oblongata. Medulla oblongata passes out through the foramen magnum and continues into spinal cord, which is contained in the neural canal of vertebral column.

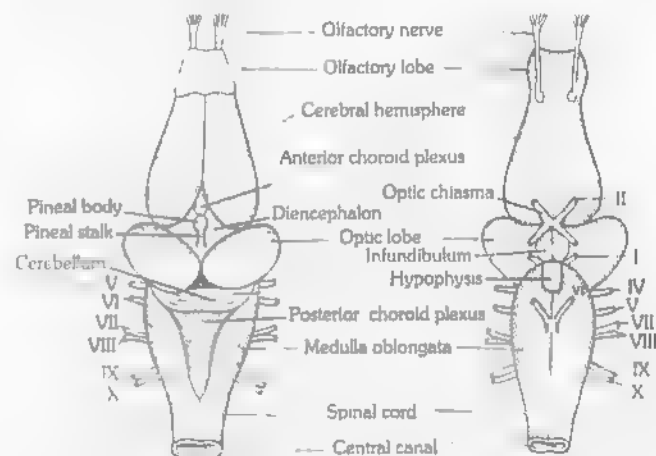


Fig : 2.4-5 Brain of frog, (a) Dorsal view, (b) Ventral view

**Cranial nerves** : The nerves which connect the brain and leave the brain box (cranium) are known as cranial nerves. The number of cranial nerves is definite in a particular group of animals. In frog, the number is ten pairs. The serial number of a nerve is also definite

**Sense organs**

Sense organs receive stimuli (changes in the environment) from outside or inside of the animals and pass impulses to the nervous system. Frog has following five types of sense organs –

(1) **Tango-receptors (organs of touch)** : These are nerve endings and touch corpuscles which are found in the skin. Nerve ending are also present in the viscera (soft internal organs).

(2) **Olfacto-receptors (organs of smell)** : They are present in the nasal epithelium of the nasal chambers

(3) **Gustato-receptors (organs of taste)** : These are found as taste buds which are present in the epithelium of the tongue and the buccopharyngeal cavity

(4) **Photo-receptors (organs of sight)** : Eyes.

(5) **Statoacoustic receptors (Hearing and balancing organs)**: Ears.

Out of these, eyes and internal ears are well organized structures and the rest are cellular aggregations around nerve ending. Eyes in a frog are a pair of large, spherical structures situated in the orbit in the dorsolateral side of head protected by eyelids. The eye ball is composed of three concentric layers, sclerotic, choroid and retina. The cornea is transparent and permit entry of light into the eye.

Ears are statoacoustic organs meant for equilibrium and hearing. Ear of frog consists of only two parts, middle and internal ears; external ear is absent. Tympanum is a dark, flat circular patch of skin found externally behind eye. Middle ear contains bony columella auris and cartilagenous stapedial plate, which passes vibrations to internal ear or membranous labyrinth.

### Endocrine system

The chemical coordination of various organs of the body is done by hormones secreted by the endocrine glands. The important endocrine glands found in a frog are pituitary, thyroid, parathyroid, thymus, pineal body, pancreatic islets, adrenals and gonads.

### Excretory system

Frog excretes urea as nitrogenous waste. It is therefore, ureotelic animal. Urinary or excretory system consists of a pair of kidneys (mesonephric), a pair of ureters, a urinary bladder, cloaca and cloacal aperture.

(1) **Kidneys** : The main organ of excretion are paired kidneys which are compact, dark red and bean like structures situated little posteriorly in the body cavity on both sides of vertebral column. Each kidney is composed of several structural and functional units called uriniferous tubules or nephrons. Each nephron has a Malpighian capsule, a neck and a coiled tubule which opens into a transverse collecting tube

(2) **Ureters** : They are fine transparent tubes which arise singly from back of kidney, proceed posteriorly and pass into cloaca. In male each ureter contains a swelling called seminal vesicle for temporary storage of sperms. Ureters of male are also called urinogenital ducts.

(3) **Urinary Bladder** : It is distensible transparent bilobed sac which is connected to cloacal chamber below the opening of ureters. Urine coming into cloacal chamber from ureters is passed into urinary bladder for storage. As the urinary bladder gets filled, the sphincter guarding opening of urinary bladder relaxes and urine flows into cloacal chamber and from here to the outside through cloacal aperture.

**Other Excretory Organs** : Liver is the organ where urea is formed from ammonia released during deamination of excess amino acids. It also synthesises bile pigments (biliverdin, bilirubin) from decomposition products of haemoglobin. Bile is passed into duodenum for elimination of waste bile pigments. In rectum a small quantity of salt is excreted by its wall into faecal matter, e.g., calcium phosphate.

### Reproductive System

Sexes are separate. Male frog is generally larger with narrower body. It has vocal sacs in the throat region for louder croaking. In breeding season male frog becomes brightly coloured. Its inner fingers develop nuptial or amplexusory pads. Female frog is generally smaller with broader body. During breeding season its abdomen swells up. Nuptial pads and vocal sacs are absent.

**Male reproductive system** : Male reproductive organs consist of a pair of elongated or ovoid yellowish testes, vasa efferentia, kidneys, urinogenital ducts and cloaca.

(1) **Testes** : Testes are found attached to the antero-ventral surface of kidneys by a double fold of peritoneum called mesorchium. Testis is composed of a large number of small tubes, the seminiferous tubules. The wall of seminiferous tubules is made up of germinal epithelium, which forms sperms by spermatogenesis

(2) **Vasa efferentia** : These are 10-12 in numbers and after arising from testes run through the mesorchium and enter the kidneys of their side. In kidneys, vasa efferentia open into Bidder's canal which is connected to the urinogenital duct through collecting tubules.

(3) **Urinogenital duct** : The urinogenital duct comes out of the kidneys and finally opens into the cloaca. Before opening into cloaca, it dilates to form a seminal vesicle to store the sperms temporarily. In some frogs the seminal vesicles are not found.

(4) **Cloaca** : The cloaca is a small median chamber that is used to pass faecal matter, urine and sperms to the exterior.

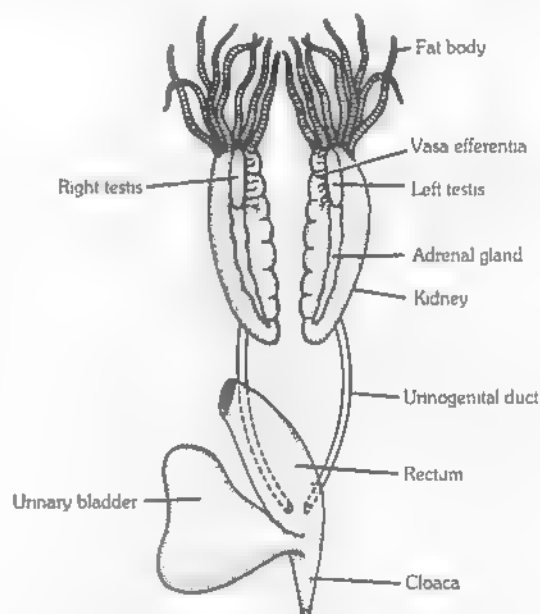


Fig : 2.4-6 Male urinogenital organs of frog

**Female reproductive system** : Female reproductive system of frog is formed of a pair of ovaries, a pair of oviducts and cloaca.

(1) **Ovaries** : A pair of ovaries, situated near kidneys, comprises the female reproductive organs. The ovaries are attached to the dorsal abdominal wall, supported by a peritoneal fold called mesovarium. The wall of ovary consists of an outermost germinal epithelium. The cells of the germinal epithelium give rise to the ovarian follicle. In each follicle, one cell becomes larger than the others cells to form ovum or female gamete by oogenesis. During the breeding season, the wall of the ovary ruptures to release the ova into the coelom. A mature female can lay 2500 to 3000 ova at a time.

(2) **Oviducts** : These are paired, white glandular, long, coiled tubes lying one on either side of the body cavity. Each oviduct consists of ovarian funnel, ovarian tubule and ovisac.



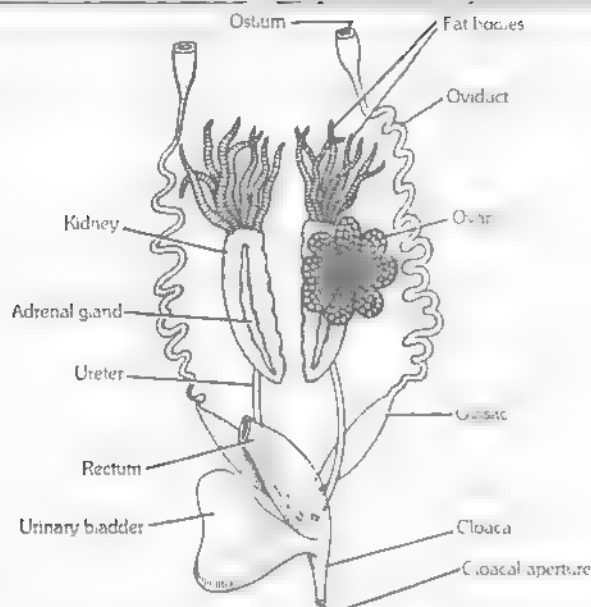


Fig : 2.4-7 Female urinogenital organs of frog

#### Interaction with Mankind

- (1) Frog is a beneficial animal for human being. It is used for laboratory study and is used as an experimental material for teaching and research.
- (2) Frog is a good friend of farmers as it eats on insect pests and this saves expenditure on pesticides
- (3) The muscular hind legs of frog are used as food by men
- (4) Small froglets are used as fish bait
- (5) Frogs maintain ecological balance because these serve as an important food link in ecosystem

#### *Rattus rattus* (The common house Rat)

##### Systematic position

Phylum	– Chordata
Subphylum	– Vertebrata or Craniata
Super Class	– Gnathostomata
Class	– Mammalia
Order	– Rodentia
Family	– Muridae
Genus	– <i>Rattus</i>
Species	– <i>rattus</i> (Black Rat)

##### Habits and Habitat

They are the common house rats which are cosmopolitan in distribution and found all over the world. They are herbivorous, fossorial and nocturnal animals and undergo hibernation. They show sexual dimorphism. They are prolific breeders. Fertilization is internal. The time interval between fertilization and birth (gestation) is about 22 to 23 days. They are completely grown at six to eight months of age. The rat breeds more than four times in a year producing 6-8 young ones in each litter. Newly born young ones are blind, deaf and without hairs. The mother feeds the young ones on milk. Average age of a rat is 3 years. The most common species are *Rattus rattus* (black rat) and *Rattus norvegicus* (brown rat or Norway rat).

##### External morphology

Their body is covered with hairs. The body is divisible into head, neck, trunk and tail.

**Head :** Head is broader posteriorly and tapers anteriorly as a naked terminal muzzle or snout. A pair of nostrils, shaped like inverted commas, is present above the mouth opening, which leads into nasal passages. Below the nostrils is the cleft upper lip, which exposes the two upper incisors. On the lateral sides of the head are large, paired bulging eyes. Eyelids have very fine and short eyelashes; the nictitating membrane is reduced. The head bears a pair of external ear or pinna at its posteriolateral position. The mouth is sub-terminal and located beneath the nostrils and remains guarded by upper and lower lips. Long, stiff, bristle-like hair known as pili lactiles or vibrissae are present on both sides of nostrils. They help the animal in measuring width of area through which the animal is to pass even in perfect darkness.

**Neck :** It is a short connection between head and trunk. With the help of neck the animal can bend its head in different directions.

**Trunk :** It is depressed fusiform major part of the body which has two parts—anterior narrow but stouter thorax and posterior wider softer abdomen. The ventral surface of female bears 6 pairs of teats or nipples, three pectoral (thoracic) and three inguinal (abdominal). The trunk bears two pairs of limbs, two forelimbs and two hindlimbs. Forelimbs are smaller than the hindlimbs. Each limb is made up of proximal segment (stylopodium), middle segment (Zeugopodium) and distal segment (autopodium). Five digits are present in autopodium of each limb. The first digit is thumb or pollex, which is much reduced with a peculiarly flattened nail and two phalanges. Nail is keratinized structure occupying position above the distal phalanx of each digit. Typical walking pads, the tori are present on the tips of digits, palm and at the base of palm. These are also present on the feet, but palms and soles do not have hair. Anus lies posteriorly at the base of tail.

**Tail :** It is quite long cylindrical and tapering structure that develops above the anus. It bears overlapping scales and sparse hair in between. Tail is used as a balancing organ.

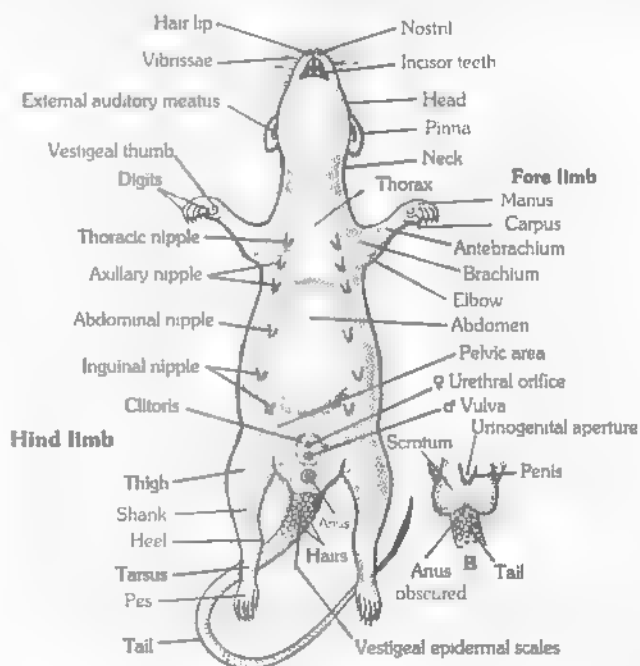


Fig : 2.4-8 External morphology of rat (a) Ventral view of female rat; (b) Ventral view of pelvic region of male rat

## Internal morphology

### Skin (Integument)

Histologically, the skin consists of outer epidermis and inner dermis.

(1) **Epidermis** : Epidermis is ectodermal in origin and is made up of stratified squamous epithelium. It consists of stratum germinativum (S. malpighi), S. spinosum, S. granulosum, S. lucidum and S. corneum. There are some layers of cells above the stratum lucidum which constitute the stratum corneum. The cells contain a protein called keratin and have lost all other internal structures including nuclei.

(2) **Dermis** : It develops from the mesoderm of embryo. It is composed of dense fibrous connective tissue with blood vessels, lymph vessels, nerve fibres, pigment cells etc.

**Derivatives of skin** : Hairs, cutaneous glands and claws are formed from the skin. Major skin glands are sudoriferous glands (sweat glands), sebaceous glands (oil glands), mammary glands (modified sweat glands), meibomian glands (modified oil glands, present along the edges of the eye lids) and ceruminous glands (wax glands, present in the external auditory canal of external ear).

### Digestive system

It consists of alimentary canal and digestive glands.

**Alimentary canal** : Alimentary canal is coiled tube of variable diameter. It begins at mouth and ends at anus. The various parts are mouth, buccopharyngeal cavity, oesophagus, stomach, small intestine (duodenum, jejunum and ileum), large intestine (caecum, colon and rectum) and anus.

(1) **Mouth** : The mouth opens in the buccal cavity that is surrounded by the vestibule, which is a space between the lips, cheeks and teeth.

(2) **Buccopharyngeal cavity** : It is a space enclosed by two jaws. Buccopharyngeal cavity consists of broader buccal cavity in the anterior region and narrow pharynx in the posterior region. Jaws bear teeth. The teeth are heterodont, thecodont and monophyodont. Each jaw carries two incisors and six molars. The incisors grow throughout life and act as growing teeth. A sharp cutting edge is maintained due to the absence of enamel on the surface. The canines and premolars are absent. A space called diastema occurs between incisors and molars. The dental formula is  $\frac{1003}{1003} \times 2 = 16$ . The middle of buccal cavity contains a muscular tongue. Taste buds occur on tongue as well as lining of buccopharyngeal cavity. Unlike frog tongue is attached posteriorly. Behind lies pharynx. Pharynx is a common chamber for the passage of food and air.

(3) **Oesophagus** : It is a short tube situated dorsal to the trachea and it leads into the pear-shaped or somewhat semicircular stomach.

(4) **Stomach** : It is wide curved part of alimentary canal which lies on the left side behind the diaphragm. It has a greater

curvature on left side, a lesser curvature on right side, cardiac orifice/valve where oesophagus opens into it and pyloric sphincter is narrow posterior and where it meets duodenum. Stomach contains goblet cells for mucus, oxyntic cells for HCl and peptic cells for secretion of pepsinogen.

(5) **Small intestine** : Stomach leads into small intestine, which can be differentiated into three parts: duodenum (U-shaped), jejunum (straight) and ileum (coiled). Digestive glands of small intestine secrete intestinal juice or succus entericus. The same contain lipase, nuclease, peptidase, lactase, sucrase and maltase enzymes.

(6) **Large intestine** : It has three parts: caecum, colon and rectum. Caecum is slightly constricted about its middle. The constriction subdivides the caecum into two parts, an apical and a basal portion. The apical portion contains a distinct mass of lymphoid tissue forming the vermiform appendix. Caecum opens into the first part of large intestine, the colon which is divisible into an ascending, a transverse and a descending colon. The descending colon leads into rectum, which opens outside through the anus.

### Digestive glands

(1) **Salivary glands** : There are three pairs of salivary glands.

(i) Sublingual glands

(ii) Submandibular glands and

(iii) Parotid glands.

Infraorbital salivary glands are reported but probably they are absent in rat, however, dogs have these glands.

(2) **Liver** : It is the largest gland of the body which is located in the upper and right side of the abdominal cavity below the diaphragm. The liver of rat consists of four lobes (left, middle, right and caudate) and the spigelian lobe is a part of caudate lobe. The cells of liver are called hepatocytes which secrete bile. Bile is carried to the duodenum by bile duct. Bile contains no digestive enzymes but helps in digestion of food in the small intestine. Gall bladder is absent in rat. Gall bladder is also absent in whale and horse.

(3) **Pancreas** : It is a very diffuse structure and is present between the duodenal loops. It secretes pancreatic juice which contains digestive enzymes such as trypsinogen (proenzyme), amylase and lipase. Islets of Langerhans of the pancreas secrete certain hormones such as insulin. Insulin converts glucose into glycogen in the liver and muscles.

(4) **Gastric glands** : These are found in stomach and secrete gastric juice containing digestive enzymes (e.g., pepsin) and hydrochloric acid (HCl) which help in digestion of food.

(5) **Intestinal Glands** : These are present in the small intestine and secrete intestinal juice containing digestive enzymes (e.g., maltase, sucrase, lipase, etc.) which help in digestion of food

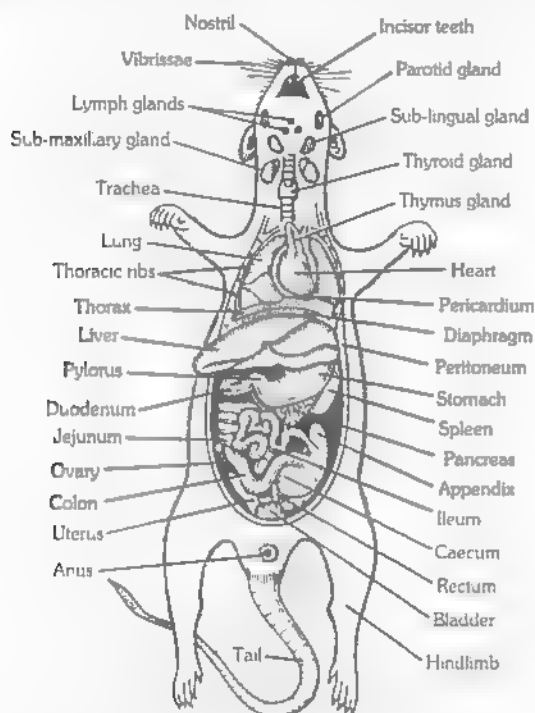


Fig : 2.4-9 General anatomy and digestive system of rat

#### Respiratory system

It consists of respiratory tract, two lungs and a mechanism for inspiration and expiration. Respiratory tract consists of nostrils, nasal chambers, internal nares, glottis, larynx, trachea, bronchi, and bronchioles. The nostrils lead into the olfactory or nasal chambers. The two nasal chambers lead into pharynx through internal nares. Pharynx contains a slit like glottis, which leads into voice box called larynx. Larynx passes into trachea and wind pipe which runs ventral to oesophagus. Trachea divides into two primary bronchi that pass into lungs. The lungs are placed one on either side of the heart lying in the thoracic cavity and are covered by visceral pleura. There are three lobes of the right lung and only one in the left. Each lung possesses a large number of alveoli where gaseous exchange occurs between air and blood

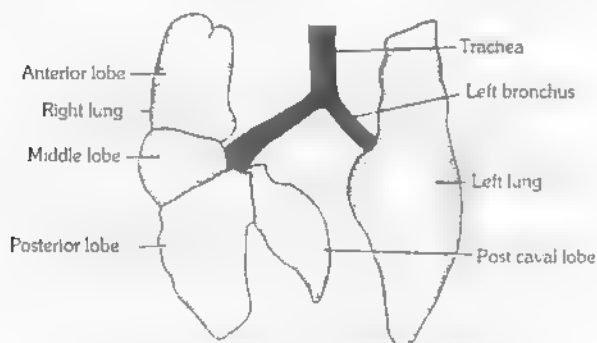


Fig : 2.4-10 Trachea and Lungs of Rat

#### Circulatory system

The circulatory system of rat consists of blood vascular system and lymphatic system

(1) **Blood vascular system** : Like other mammals rat possesses closed and double circulation. Blood vascular system comprises blood, heart and blood vessels

**Blood** : The volume of blood is about 5-7 ml/100 gm body weight. The blood consists of blood plasma and three types of blood corpuscles namely RBCs (6-7 lac/cubic microlitre), WBCs (6-10 thousands/cubic microlitre) and platelets. RBCs are without nucleus on maturation. They contain haemoglobin (respiratory pigment). WBCs provide immunity and defence against diseases. The platelets help in clotting of blood.

**Heart** : The heart lies on the midline and placed obliquely in the thoracic cavity, surrounded by pericardial cavity. The heart has four chambers; the right atrium and right ventricle and the left atrium and left ventricle. Blood flows from the right atrium into the right ventricle via the tricuspid valve (right atrio-ventricular valve) with three cusps of fibrous tissue. Blood flows from the left atrium into the left ventricle via the bicuspid or mitral valve (left atrio-ventricular valve). Aortic and pulmonary valves each have three leaflets and called semilunar valve. The right cardiac arteries supply right and left atria, whereas the left cardiac arteries only supply to small portion of the left atrium. Well developed arterial and venous system similar to other mammals is found in the rat. Only the left aortic arch is present and two precavae are present in the rat. Hepatic portal system is present which comprises veins collecting blood from alimentary canal and supply to the liver after branching in capillaries. The renal portal system is absent.

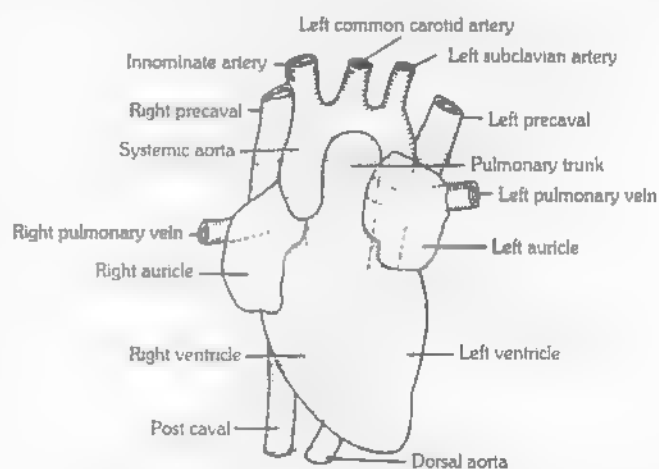


Fig : 2.4-11 Heart of rat in ventral view

(2) **Lymphatic system** : It consists of lymph, lymph vessels and lymph nodes. Lymph is colourless fluid which is similar to blood but lacks red blood corpuscles and blood platelets. Lymph is formed by lymph capillaries from tissue fluid. Lymph capillaries join to form lymph vessels. At places lymph vessels bear lymph nodes. The latter contain minute channels where germs are entrapped by leucocytes. Lymph nodes also produce lymphocytes. Tonsils a type of lymphatic node are, however, absent. Lymph vessels form lymph ducts of two types, right and thoracic. They also open into veins.

### Excretory system

The excretory system includes paired kidney, ureters, a urinary bladder and urethra.

(1) **Kidneys** : There is a pair of kidneys which are dark red and bean shaped. The right kidney is slightly higher in position. The kidney consists of outer cortex and inner medulla. A kidney has numerous structural and functional units called nephrons (= uriniferous tubules). Each nephron is made up of Bowman's capsule, proximal convoluted tubule (PCT), Henle's loop and distal convoluted tubule (DCT). The Bowman's capsule is a cup shaped structure which contains a meshwork of blood capillaries, the glomerulus. Filtration of metabolic wastes takes place in the glomerulus. Filtrate comes to the Bowman's capsule from the glomerulus and then to the other parts of the nephron.

(2) **Ureters** : There is a pair of ureters. Each ureter arises from each kidney. Ureters carry urine from the kidneys to the urinary bladder

(3) **Urinary bladder** : It is muscular sac-like structure in which two ureters open. The urinary bladder stores urine temporarily

(4) **Urethra** : In male it carries both urine and semen. In female it carries urine only. Thus in male rat there is only one urinogenital aperture to pass urine and semen. However in female rat both urinary and genital apertures are separate.

### Nervous system

The nervous system is divisible into three main parts :

(1) **Central Nervous System (CNS)** : It is a hollow, dorsally placed structure lying along the middorsal axis of the body. It comprises the brain and spinal cord. The brain is lodged in the skull while spinal cord is enclosed by the vertebral column.

(2) **Peripheral Nervous system (PNS)** : The nerves arising from the central nervous system constitute the peripheral nervous system. The nerves which originate from the brain and spinal cord are known as cranial nerves and spinal nerves respectively.

(3) **Autonomic Nervous System (ANS)** : It controls and coordinates such organs which are under involuntary control. It consists of sympathetic and parasympathetic nervous system.

**Brain** : The brain is lodged in the cranial cavity (= cranium of the skull). It is covered by three membranes called meninges. The inner most membrane is called pia mater, the next is the arachnoid mater (= arachnoid membrane) and outer most is the duramater. The sub dural space is present below the dura mater and sub arachnoid space lies below the arachnoid mater. These spaces are filled with a fluid. The meninges are protective in function

The brain is composed of two large hemispheres separated by a median fissure. The cerebral hemispheres form the largest part of the brains. The posterior portion of the brain is composed of medulla oblongata which tapers in the spinal cord. The spinal cord

is a long tube like thick walled structures which emerges out through the foramen magnum of the skull and passes through neural canal of vertebral column. The peripheral nervous system comprises the nerves arising from the brain and spinal cord.

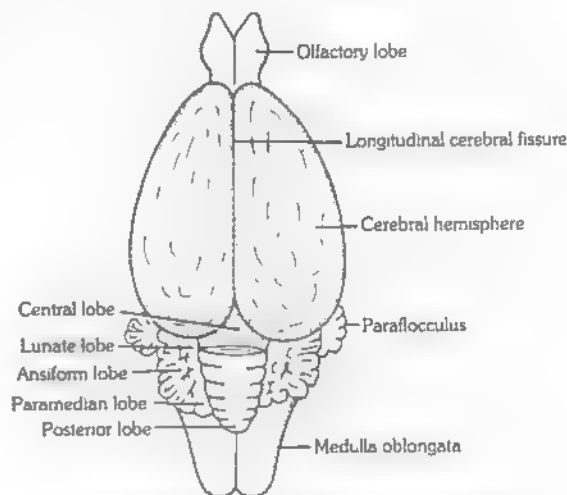


Fig : 2.4-12 Dorsal view of the brain of Rat

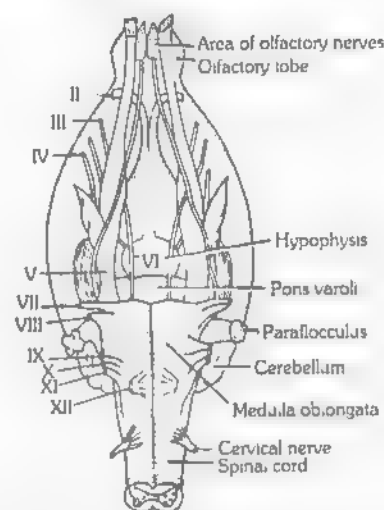


Fig : 2.4-13 Ventral view of the brain of Rat

**Cranial nerves** : Rat has 12 pairs of cranial nerves originating from brain.

**Spinal Nerves** : 33 pairs which come out from intervertebral foramina. Spinal nerves are mixed. They supply various organs in the area of their origin.

### Sense Organs

Skin has tangoreceptors (receptors of touch), thermoreceptors (receptors of temperature) algosoreceptors (receptors for pain) and rheoreceptors (receptors for current or vibrations). Gustatoreceptors (taste receptors) occur in the form of taste buds over tongue and posterior part of palate. Olfactoreceptors are located in olfactory epithelium present in nasal chambers. They perceive the sensation of smell. Smell is also perceived by a pair of Jacobson's organs present in the wall of buccal cavity of Rat. Organs of sight are eye while statoacoustic organs are ears.

## Reproductive system

**Male Reproductive system :** The male reproductive organs of a rat are a pair of testes, epididymis, vas deferens, urethra, penis and spermatic cord.

(1) **Testes :** A pair of testes is found in the scrotal sacs. Each testis is an elongated and ovoid body attached posteriorly to scrotal sac by gubernaculum. Testis of male rat descends in the scrotal sacs between the 30<sup>th</sup> to 40<sup>th</sup> day of life through inguinal canal. The inguinal canal remains open through out life, but during sexually inactive period, the testis may be withdrawn into abdominal cavity.

(2) **Epididymis :** These are paired structure. Each epididymis is a mass of long narrow coiled tubule lying along the testis which consists of anterior caput epididymis, middle corpus epididymis and posterior cauda epididymis. Epididymis stores the sperms.

(3) **Vasa deferentia :** There is a pair of vasa deferentia. A vas deferens arises from the cauda epididymis. Vasa deferentia carry sperms.

(4) **Seminal vesicles :** There is a pair of seminal vesicles which are large and lobulated except for the smooth tip which is doubled back upon itself. They are not store houses for sperms. Their secretion is alkaline and forms the bulk of seminal fluid (semen).

(5) **Urethra :** It is divided into three parts –

- (i) Prostatic urethra is surrounded by the prostate gland.
- (ii) Membranous urethra is the shortest portion and runs from the prostate to the bulb (base) of the penis.
- (iii) Penile urethra passes through the penis and opens at the tip of the penis as urinogenital aperture.

(6) **Penis :** It is a copulatory organ which is covered by a loose sheath, the prepuce. The penis of the rat has a bony process called the os penis. Penis bone is also present in bat, dog, walrus and whale

**Accessory Glands :** Male accessory sex glands –

(1) **Ampullary glands :** The outer end of the vas deference near the entrance into the urethra is enlarged into ampulla, which contain ampullary glands to secrete mucus

(2) **Vesicular glands :** These are branched glands which originate from the vas deferens behind the ampulla.

(3) **Coagulating glands :** Closely applied along the minor curvature of the seminal vesicles and within the same sheath are the coagulating glands. The secretion of these glands serve to coagulate the seminal fluid (Semen).

(4) **Prostate glands :** There are two prostate glands whose secretion is rich in citric acid, lipid and acid phosphatase.

(5) **Cowper's glands :** (Bulbo-urethral glands) : These are one pair which originate from the urethra at the base of penis. They produce a secretion during sexual excitement which protects the sperms from traces of acids found in the urethra (as the urine also passes through the penile urethra).

(6) **Preputial glands (Glands of Tyson) :** They develop from the skin forming prepuce. They are modified sebaceous (oil) glands which secrete peculiar odorous secretion.

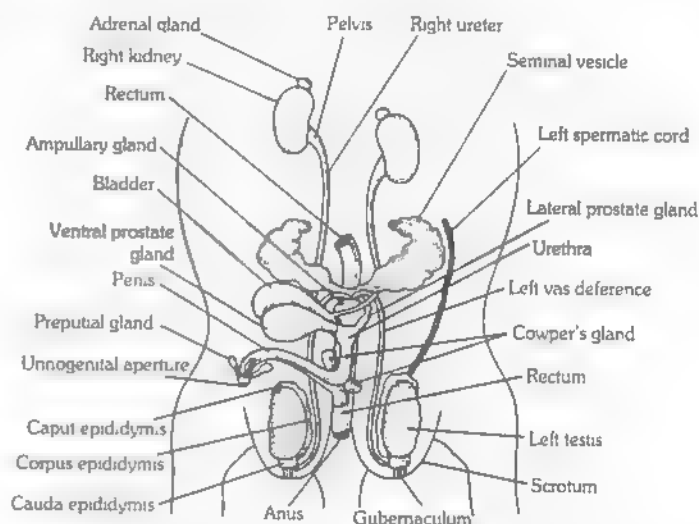


Fig : 2.4-14 Male urinogenital organs of rat

**Female reproductive system :** The female reproductive organs consists of a pair of ovaries, fallopian tubes two uteri, a single common vagina and a clitoris. Female rats mature rapidly and becomes sexually mature in about 72 days.

(1) **Ovaries :** Ovaries are paired small yellowish compact structure suspended in the body cavity by mesovarium.

(2) **Fallopian Tubes (Oviducts or uterine tubes) :** There is one pair of convoluted Fallopian tubes. Each Fallopian tube begins with fimbriated funnel which receives ova from the ovary. As the fertilization is internal, it takes place in the dilated upper most portion of the Fallopian tubes.

(3) **Uterus (Womb) :** The uterus is a hollow muscular structure. The uterine horns are fused near vagina. The wall of the uterus consists of outer covering of peritoneum, the perimetrium, middle layer of smooth muscle fibres, the myometrium and inner layer of simple columnar epithelium, the endometrium. The embryo gets attached to the uterine wall through placenta. Embryonic development takes place in the uterus. Placenta provides the physiological connection between developing foetus and uterine wall (endometrium) of the mother.

(4) **Vagina :** It is a tubular structure which extends from the uterus and opens outside as vaginal opening (= vulva). Penis of the male rat is inserted into the vagina during copulation. The vagina also helps to deliver the young ones at the time of birth.

(5) **Clitoris :** It corresponds to the penis of the male but it is reduced in size and does not have any passage (it is solid structure). The clitoris is found anterior to the vulva.

### Accessory Glands

(1) **Vestibular glands :** These are small mucous glands which open on the surface of the vestibule of the vagina.

(2) **Bulbo-urethral glands :** These are small glands which are present in relation with the urethra

(3) **Preputial glands** : There is one pair of large preputial glands which are near the tip of the clitoris.

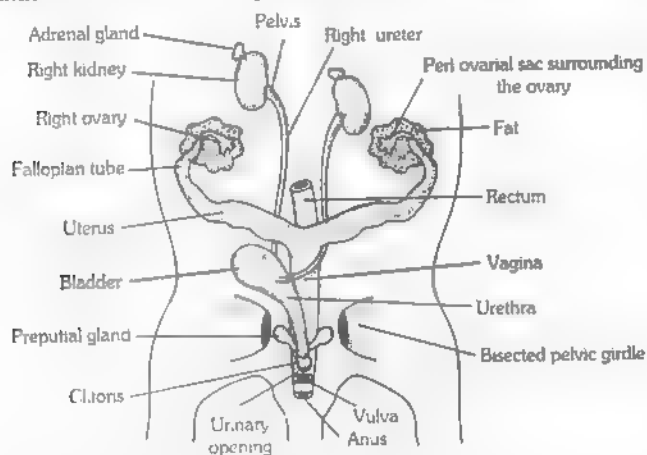


Fig : 2.4-15 Female urinogenital organ of rat

#### Interaction with mankind

(1) Rat is an important pest of crops, stored grains, fruits, vegetables, etc.

(2) Rat destroys field by making burrows and tunnels which often provide shelter to snakes.

(3) Rat makes burrows in the houses and causes damage to the household including books, clothes, food, etc.

(4) Rat is a host of rat flea, *Xenopsylla*, which is the vector for the disease bubonic plague.

(5) Rat is an important component of food chain as several animals like cats, snakes, mongoose, owls and some other birds use it as their food.

(6) The albino rat that is commonly used for teaching and researches in institutions is a product of laboratory breeding.

(7) The albino rats are also used as an experimental animal to test drugs that are to be finally used by the human beings.

**Note :** See Morphology, Anatomy and functions of different systems (digestive, circulatory, respiratory, nervous and reproductive) of an insect (cockroach) is given in the chapter 1.7 Animalia (Phylum Arthropoda) page no. 206.

## Tips & Tricks

✍ Frog's skin is not concerned with thermoregulation. There is no synthesis of vitamin D in the skin of frog. Frog can absorb water through the skin.

✍ Digit formula of fore limb of frog is 0, 2, 2, 3, 3. Digital formula of hind limb of frog is 2, 2, 3, 4, 3.

✍ Largest Frog : *Rana goliath* (35 cm).

✍ The scientific study of body movements is known as kinesiography.

✍ Wistar Rat is an inbred strain of rats, homozygous for most traits, produced by strict brother-sister inbreeding over many generations to develop animals for research with the same general genetic composition (Wistar Institute).

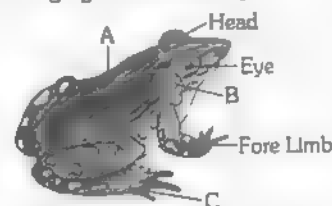
✍ Rat population is 70 times that of humans. 6 rats consume food equivalent to one human being.

## OT Ordinary Thinking

### Objective Questions

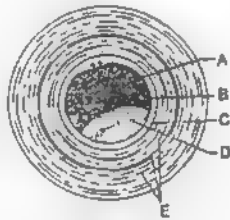
#### Morphology of Frog

1. Frogs and toads belong to the order [Odisha JEE 1995]  
(a) Anura (b) Apoda  
(c) Caudata (d) Gymnophiona
2. The cloaca in frog is a common chamber for the urinary tract, reproductive tract and [Kerala PMT 2008; AFMC 2010]  
(a) Alimentary canal (b) Portal system  
(c) Hepatic portal vessels (d) Notochord  
(e) Lymphatic system
3. Which one of the following is not a characteristic feature of frog [Kerala PMT 2009]  
(a) The skin is moist and slimy  
(b) Each of the fore limbs and hind limbs end in five digits  
(c) Hepatic portal and renal portal systems are present  
(d) Skin, buccal cavity and lungs are the respiratory organs  
(e) Heart is three-chambered
4. See the following figure and identify A to C respectively [NCERT]



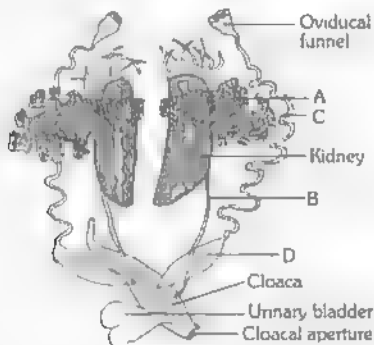
- (a) Neck, Tympanum, Hind limb  
(b) Trunk, Tympanum, Hind limb  
(c) Neck, Brown eye spot, Web  
(d) Trunk, Tympanum, Web
5. The scientific name of common toad is  
(a) *Hyla arborea* (b) *Xenopus laevis*  
(c) *Bufo melanostictus* (d) *Bombinator igneus*
6. The toad possesses [BVP 2001]  
(a) Bifid tongue, slippery skin and mucous glands  
(b) Salivary glands, mucous glands and parotid glands  
(c) Parotid glands, warty skin and semicircular snout  
(d) Slippery skin, yellow pigment and abundant mucous glands
7. Parotid glands are found in  
(a) *Bufo* (b) *Hyla*  
(c) *Rana* (d) *Alytes*
8. Which statement is true about the venous blood vessels of frog [AMU (Med.) 2010]  
(a) Lingual and submandibular unite to form the internal jugular  
(b) Musculo-cutaneous and brachial unite to form the subclavian  
(c) The ventral abdominal vein drains into the posterior vena cava  
(d) The pelvic veins unite to form the renal portal vein
9. Frog hibernate during  
(a) Winter (b) Spring  
(c) Summer (d) autumn
10. The summer sleep of frog is termed as  
(a) Neoteny (b) Aestivation  
(c) Paedogenesis (d) Hibernation

11. The following is a diagram of the just spawned frog's egg; with the parts labelled from A to E. Identify the parts and choose the correct option from those given below



[KCET 2006]

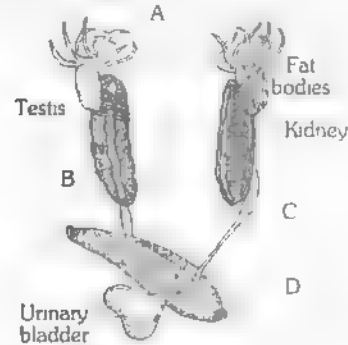
- (a) A= cytoplasm, B= plasma membrane, C= vitelline membrane, D= yolk, E= jelly coat  
 (b) A= cytoplasm, B= vitelline membrane, C= plasma membrane, D= yolk, E= jelly coat  
 (c) A= yolk, B= plasma membrane, C= vitelline membrane, D= cytoplasm, E= jelly coat  
 (d) A= yolk, B= jelly coat, C= vitelline membrane, D= cytoplasm, E= plasma membrane
12. Dissection of frog is done from ventral side because  
 (a) Ventral skin is soft  
 (b) Abdominal vein is present ventrally  
 (c) Vertebral column is present on dorsal side  
 (d) All of these
13. The given figure is related with female reproductive system of frog. Identify A to D [NCERT]



	A	B	C	D
(a)	Ovary	Urinogenital duct	Bidder's canal	Oviduct
(b)	Ovary	Urinogenital duct	Ovisac	Oviduct
(c)	Ovary	Urinogenital duct	Bidder's canal	Ovisac
(d)	Ovary	Ureter	Oviduct	Ovisac

14. Male frogs can croak louder than females because of  
 (a) Vocal sacs (b) Stronger  
 (c) Larger in size (d) Larger sound box
15. Croaking of frog is [AIIMS 1996; EAMCET 1999; CPMT 2000]  
 (a) Hunger call (b) Danger call  
 (c) Musical tone (d) Sex call for female
16. The development of frog is  
 (a) Direct (b) Indirect  
 (c) Parthenogenetic (d) None of these
17. How many eggs are laid by a female frog at a time  
 (a) 100 - 200 (b) 500 - 1000  
 (c) 2500 - 3000 (d) 5000 - 6000

18. The opening of rectum in frog is called [CBSE PMT 2000]  
 (a) Vestibule (b) Cloaca  
 (c) Cocyx (d) None of the above
19. A common cloacal aperture is found in  
 (a) *Rana* (b) *Nereis*  
 (c) Rabbit (d) *Pheretima*
20. Observe the following figure indicating the male reproductive system of frog. Identify A, B, C and D [NCERT]

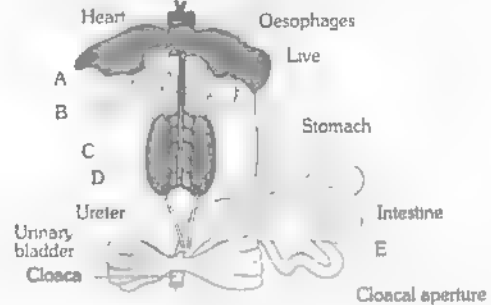


	A	B	C	D
(a)	Vasa efferentia	Thyroid gland	Urinogenital duct	Cloaca
(b)	Vasa efferentia	Adrenal gland	Urinogenital duct	Cloaca
(c)	Bidder's canal	Adrenal gland	Urinogenital duct	Cloaca
(d)	Bidder's canal	Adrenal gland	Urinogenital duct	Rectum

21. Disappearance of the tadpole tail during metamorphosis is brought about by [AMU (Med.) 2010]  
 (a) Endoplasmic reticulum (b) Golgi bodies  
 (c) Lysosomes (d) Peroxisomes
22. The number of fingers in the hindlimb of frog is [NCERT]  
 (a) 4 (b) 5  
 (c) 6 (d) 7
23. In the buccal cavity of frog the internal nares are  
 (a) One (b) Two  
 (c) Fused (d) Absent
24. Mucus helps frog in making [CBSE PMT 1993]  
 (a) Dry skin (b) Moist skin  
 (c) Rough skin (d) Thick skin
25. Acrosome of the sperm of frog helps in fertilization by  
 (a) Activating the oocyte to engulf the sperm  
 (b) Inducing formation of cone of reception in oocyte  
 (c) Stimulating oocyte to undergo second maturation division  
 (d) Secreting sperm lysin to dissolve covering membrane of oocyte
26. Chromatophores in skin of frog found in stratum [CBSE PMT 1992, 93]  
 (a) Corneum (b) Compactum  
 (c) Germinativum (d) Mostly spongiosum
27. One of the main functions of frog's skin is [NCERT; CBSE PMT 1991]  
 (a) Diffusion of respiratory gases  
 (b) Absorption of ultraviolet rays to produce vitamin D  
 (c) Storage of excess food in the form of subcutaneous fat  
 (d) Excretion of nitrogenous waste in the form of uric acid

28. When a sperm enters an egg of frog  
(a) First polar body is formed  
(b) First meiotic division occurs  
(c) Second meiotic division occurs  
(d) Fertilization process is completed
29. In frog, jelly around the eggs is deposited in [BHU 2000]  
(a) Ovary (b) Oviduct  
(c) Water after fertilization (d) Water during fertilization
30. Consider the following four statements (A – D) related to the common frog *Rana tigrina* and select the correct option stating which ones are true (T) and which ones are false (F)  
**Statements :**  
(A) On dry land it would die due to lack of  $O_2$  if its mouth is forcibly kept closed for a few days  
(B) It has four-chambered heart  
(C) On dry land it turns uricotelic from ureotelic  
(D) Its life-history is carried out in pond water  
**Options** [NCERT; CBSE PMT (Mains) 2011]  
(A) (B) (C) (D)  
(a) F F T T  
(b) F T T F  
(c) T F F T  
(d) T T F F
31. A Bidder's canal in each kidney of frog  
(a) Runs longitudinally in lateral region of kidney  
(b) Runs longitudinally in medial region of kidney  
(c) Runs transversely across the width of anterior part of kidney  
(d) Runs transversely across the width of posterior part of kidney
32. In frog, the surface of attachment of tongue is [CBSE PMT 1992, 97]  
(a) Palatine (b) Sphenoid  
(c) Pterygoid (d) Hyoid apparatus
33. Read the statements with regard to frog. Which of the statement(s) is/are correct and incorrect  
1. The medulla oblongata passes out through foramen of Monro and continues into spinal cord  
2. Vasa efferentia are 10-12 in number that arise from testes  
3. Ovaries have no functional connection with kidneys  
4. Frogs are uricotelic [Kerala PMT 2011]  
(a) 1, 2 and 3 are correct but 4 is incorrect  
(b) 1 and 2 are correct while 3 and 4 are incorrect  
(c) 2 and 3 are correct while 1 and 4 are incorrect  
(d) 2, 3 and 4 are correct while 1 is incorrect  
(e) 3 and 4 are correct while 1 and 2 are incorrect
34. In frog pyloric sphincter is located between  
(a) Fundus and pylorus (b) Cardiac and fundus  
(c) Oesophagus and pharynx (d) Stomach and duodenum
35. In frog, digestion of fats occurs mostly in [NCERT; CBSE PMT 1993]  
(a) Rectum (b) Stomach  
(c) Duodenum (d) Small intestine

36. A fully grown tadpole larva of frog respire through [BCECE 2001]  
(a) Gills (b) Skin  
(c) Lungs (d) Tail fin
37. The given figure is related to diagrammatic representation of internal organs of frog. Identify A to E [NCERT]



	A	B	C	D	E
(a)	Gall bladder	Lung	Fat bodies	Kidney	Rectum
(b)	Gall bladder	Lung	Testis	Kidney	Rectum
(c)	Gall bladder	Lung	Fat bodies	Testis	Rectum
(d)	Gall bladder	Lung	Ovary	Testis	Rectum

38. If the mouth of frog is kept open for some time, it dies because it is unable to  
(a) Eat (b) Drink  
(c) Breathe (d) None of these
39. During hibernation, frog respire with [Manipal 2001; CBSE PMT 2001]  
(a) Lung only (b) Moist skin only  
(c) Buccal cavity only (d) External gills and lungs
40. Oxygen carrier or the respiratory pigment in blood of frog and other vertebrates is [CPMT 1992]  
(a) Myoglobin (b) Cytochrome  
(c) Haemoglobin (d) Haemocyanin
41. A frog must swallow air to expand the lungs because frog  
(a) Has no diaphragm  
(b) Has no vagus nerve  
(c) Is relatively primitive vertebrate  
(d) Normally breathe through its skin
42. In frog, glottis is controlled by muscles of  
(a) Sternum (b) Vocal cords  
(c) Pectoral girdle (d) Arytenoid cartilages
43. The lungs in frogs are  
(a) Compact spongy masses  
(b) Thin-walled elastic, hollow bags  
(c) Thick-walled nonelastic, hollow bags  
(d) Thick-walled nonelastic solid masses
44. In frog, respiration occurs by [NCERT]  
(a) Lungs (b) Trachea  
(c) Gills only (d) Both (a) and (b)
45. In which of these animals, skin serves as an accessory organ of respiration [CBSE PMT 1990; WB JEE 2010]  
(a) Bird (b) Frog  
(c) Lizard (d) Rabbit



46. In frog, cutaneous respiration takes place  
[NCERT; CBSE PMT 1992]  
(a) Always  
(b) Only on land  
(c) Only in water with pulmonary respiration  
(d) Only in water pulmonary respiration is not occurring
47. The epithelial lining of respiratory system in frog is derived by  
[CPMT 1993]  
(a) Ectoderm  
(b) Endoderm  
(c) Mesoderm  
(d) Mesoderm and endoderm
48. Frogs differ from humans in possessing  
[NCERT; AFMC 1997; MP PMT 2007; CBSE PMT (Mains) 2011]  
(a) Nucleated red blood cells  
(b) Thyroid as well as parathyroid  
(c) Paired cerebral hemispheres  
(d) Hepatic portal system
49. Heart of frog differs from that of man by presence of  
[NCERT]  
Or  
Heart of rat differs from that of frog by the absence of  
(a) Two aortae (b) Mitral valve  
(c) Sinus venosus (d) Four-chambers
50. The sinus venosus is located on  
(a) Dorsal surface of the heart of frog  
(b) Ventral surface of the heart of frog  
(c) Dorsal surface of the heart of rabbit  
(d) Ventral surface of the heart of rabbit
51. In frog  
[CBSE PMT 1991]  
(a) Acetylcholine is the only neurotransmitter  
(b) Noradrenaline is the only neurotransmitter  
(c) Both acetylcholine and noradrenaline act as neurotransmitters  
(d) Neither acetylcholine nor noradrenaline acts as neurotransmitter
52. Amphibian heart is  
[NCERT; AFMC 2001]  
(a) One-chambered (b) Three-chambered  
(c) Two-chambered (d) Four-chambered
53. Ureters act as urinogenital ducts in  
[NCERT; CBSE PMT 1991, 92; CBSE PMT (Mains) 2011]  
(a) Frog's both males and females  
(b) Frog's males  
(c) Human males  
(d) Human females
54. Mesorchium in frog refers to  
[NCERT; CBSE PMT 1990]  
(a) Fold of peritoneum between a kidney and a testis  
(b) Internal tissue of testes  
(c) Capsules of testes  
(d) None of these
55. When heart of frog is cut, it will  
(a) Not beat at all  
(b) Stop beating soon after  
(c) Continue to beat for a long time it kept dry  
(d) Continue to beat for a long time it kept moist
56. The heart of frog beats at the rate of  
(a) 25 times/min. (b) 64 times/min  
(c) 72 times/min. (d) 100 times/min.
57. The venous system of frog differs from that of rabbit in having  
(a) Hepatic vein (b) Three vena cavae  
(c) Renal portal system (d) Hepatic portal system
58. In frog, the vein that carries blood from tongue is termed  
(a) Lingual (b) Azygous  
(c) Cutaneous (d) Anterior abdominal
59. Sciatic vein of frog opens in  
[BHU 2005]  
(a) Heart (b) Kidney  
(c) Pelvic region (d) Liver
60. Chromatophores in frog's skin are controlled by  
[CBSE PMT 1992]  
(a) Hormones  
(b) Environment  
(c) Nervous activity  
(d) Nervous and hormonal activities
61. Match the following column I with column II and choose the correct combination.
- |     | Column I  |       | Column II |
|-----|-----------|-------|-----------|
| (a) | Earthworm | (i)   | Gizzard   |
| (b) | Cockroach | (ii)  | Caecum    |
| (c) | Frog      | (iii) | Clitellum |
| (d) | Rat       | (iv)  | Cloaca    |
- [Kerala CET 2005]  
(a) (a) – (i), (b) – (ii), (c) – (iv), (d) – (iii)  
(b) (a) – (iii), (b) – (i), (c) – (iv), (d) – (ii)  
(c) (a) – (iii), (b) – (i), (c) – (ii), (d) – (iv)  
(d) (a) – (i), (b) – (iii), (c) – (iv), (d) – (ii)
62. Fenestra ovalis in frog is the  
[CBSE PMT 1992; KCET 2001; MHCET 2002]  
(a) Air-filled cavity of middle ear  
(b) Communication between pharynx and tympanic cavity  
(c) External opening of tympanic cavity covered by tympanic membrane  
(d) Opening of auditory capsule which separates middle ear from internal ear
63. Main excretory organs in a frog are  
(a) Skin (b) Lungs  
(c) Kidneys (d) Malpighian tubules
64. In frog, sclerotic is  
(a) Bony (b) Fibrous  
(c) Cartilaginous (d) None of these
65. The ciliated funnels on the ventral side of the kidney in frog are called  
(a) Ostia (b) Nephrostomes  
(c) Corpora adiposa (d) Bidder's organ
66. How do you differentiate a frog from a toad  
[KCET 2011]  
(a) Frog has no exoskeleton but toad had scales  
(b) Frog respire through lungs but toad respire through skin  
(c) Frog has a tail but toad has no tail  
(d) Frog has no parotid glands but toad has a pair of parotid glands
67. In frog the urinary bladder is  
[NCERT]  
(a) Absent (b) Paired  
(c) Bilobed (d) None of these

68. When an electric shock is given to the leg of a pithed frog it  
(a) Blinks its eyes (b) Shows no response  
(c) Put out its tongue (d) None of these
69. Which of these is an ear ossicle in frog [CBSE PMT 1990]  
(a) Incus (b) Auricle  
(c) Malleus (d) Columella auris
70. Nitrogenous excretory product of tadpole of frog is  
[CBSE PMT 1992, 93]  
(a) Urea (b) Guanine  
(c) Uric acid (d) Ammonia
71. A frog has  
(a) Eyes but no lids (b) Jaws but no teeth  
(c) Hands but not fingers (d) Ears but not pinnae
72. Which of the following is absent in frog  
(a) External ear (b) Middle ear  
(c) Internal ear (d) None of these
73. Which part of the brain of frog is called pallium  
(a) Roof of paracoel (b) Floor of epicoel  
(c) Roof of rhinocoel (d) Roof of metacoel
74. Number of spinal nerves in frog is [CPMT 2010]  
(a) Ten only (b) Ten pairs  
(c) Twelve pairs (d) Twenty pairs
75. What will happen if the eyes of a frog are covered by paper  
[CBSE PMT 1990]  
(a) Frog will soon die  
(b) Frog will not move  
(c) Frog will not do any thing  
(d) Frog will move to one side only
76. The second cranial nerve of frog is  
(a) Optic (b) Vagus  
(c) Auditory (d) Trochlear
77. Eighth cranial nerves of frog connects the brain to  
(a) Nose (b) Ears  
(c) Tongue (d) Pharynx
78. Select the correct route for the passage of sperms in male frogs [NEET 2017]  
(a) Testes → Bidder's canal → Kidney → Vasa efferentia → Urinogenital duct → Cloaca  
(b) Testes → Vasa efferentia → Kidney → Seminal vesicle → Urinogenital duct → Cloaca  
(c) Testes → Vasa efferentia → Bidder's canal → Ureter → Cloaca  
(d) Testes → Vasa efferentia → Kidney → Bidder's canal → Urinogenital duct → Cloaca
79. Frog's heart when taken out of the body continues to beat for sometime  
Select the best option from the following statements  
(A) Frog is a poikilotherm  
(B) Frog does not have any coronary circulation  
(C) Heart is "Myogenic" in nature  
(D) Heart is autoexcitable  
Options [NEET 2017]  
(a) Only (C) (b) Only (D)  
(c) (A) and (B) (d) (C) and (D)

## Morphology of Rat

1. The most important mammalian character of rat is  
(a) Hair (b) Pinna  
(c) Diaphragm (d) Mammary glands
2. The second layer of epidermis in rat integument is [Kerala PMT 2009]  
(a) Stratum lucidum (b) Stratum germinativum  
(c) Stratum corneum (d) stratum granulosum  
(e) Dermis
3. In rat, testes lie in  
(a) Scrotum (b) Thoracic cavity  
(c) Abdominal cavity (d) Retroperitoneal position
4. Rats are  
(a) Arboreal (b) Fossorial  
(c) Scansorial (d) None of these
5. The common brown rat is  
(a) *Rattus rattus* (b) *Rattus melsata*  
(c) *Rattus norvegicus* (d) *Bandicota bengalensis*
6. The three parts of the limb of a rat from proximal to distal end are  
(a) Autopodium, zeugopodium and stylopodium  
(b) Stylopodium, zeugopodium and autopodium  
(c) Stylopodium, autopodium and zeugopodium  
(d) Zeugopodium, autopodium and stylopodium
7. Accessory glands associated with the genital organs in female rats are  
(i) Vestibular Bartholins (ii) Cowper's glands  
(iii) Ampullary glands (iv) Vesicular gland [Kerala PMT 2009]  
(a) (i) and (ii) (b) (iii) and (iv)  
(c) (iv) only (d) (iii) only  
(e) (i) only
8. The chromosome number in *Rattus rattus* is  
(a) 40 (b) 42  
(c) 44 (d) 38
9. How many nipples are present in a female rat  
(a) Two pairs (b) One pairs  
(c) Three pairs (d) Six pairs
10. The teeth of rat are  
(a) Homodont, acrodont and diphyodont  
(b) Heterodont, thecodont and diphyodont  
(c) Heterodont, thecodont and polyphyodont  
(d) Heterodont, pleurodont and polyphyodont
11. Which of the following teeth are absent in a rat  
(a) Canines and molars (b) Incisors and molars  
(c) Incisors and premolars (d) Canines and premolars
12. The total number of teeth in a rat  
(a) 10 (b) 16  
(c) 20 (d) 28
13. Which type of placenta is found in a rat  
(a) Epitheliochorial (b) Haemochorial  
(c) Haemoendothelial (d) Endotheliochorial
14. A diastema is found in  
(a) Rat (b) Man  
(c) Both (d) None
15. Premolars are absent in  
(a) Rat (b) Elephant  
(c) Both of these (d) None of these

16. The life span of rat is about  
(a) Two years (b) Four years  
(c) Six years (d) Eight years
17. Which of the following is present in a rat not in a frog  
(a) Ileum (b) Jejunum  
(c) Stomach (d) Duodenum
18. Select the false statement [Kerala PMT 2006]  
(a) In rats the teeth are heterodont and thecodont  
(b) In female rats, the urinary and genital apertures are located above anus  
(c) In female rats, six pairs of nipples are present on the ventral surface of the trunk  
(d) In rats, 12 pairs of cranial nerves and 33 pairs of spinal nerves are present  
(e) In rats, the gestation period is 22 – 23 days
19. Which type of circulation is found in rat  
(a) Open and double (b) Open and single  
(c) Closed and single (d) Closed and double
20. Gestation period of rat is  
(a) 20-22 days (b) 28-32 days  
(c) 52-65 days (d) 60-65 days
21. The site of fertilization in rat is  
(a) Vagina (b) Uterus  
(c) Vestibule (d) Fallopian tube
22. How many meninges are present in rat  
(a) Two (b) Three  
(c) Four (d) Many
23. Which aortic arch is present in a rat  
(a) Left (b) Right  
(c) Both (d) None
24. Hepatic portal system collect blood from  
(a) Liver (b) Lungs  
(c) Kidney (d) Alimentary canal
25. Which of the following is absent in a rat  
(a) Tonsils (b) Renal portal  
(c) Gall bladder (d) All of these
26. The kidney in rat are  
(a) Holonephros (b) Pronephros  
(c) Mesonephros (d) Metanephros
27. Where do you find Graafian follicles of a rat  
(a) Ovary (b) Brain  
(c) Kidney (d) Thyroid
28. Rat is  
(a) Oviparous (b) Viviparous  
(c) Ovoviviparous (d) Parthenogenetic
2. Layer of actively dividing cells in skin of frog is termed as stratum [CBSE PMT 1993]  
(a) Malpighi (b) Corneum  
(c) Compactum (d) Spongiosum
3. When a frog is transferred from 20°C to 30°C, its body temperature  
(a) Falls to 15°C (b) Rises to 30°C  
(c) Falls to 12°C (d) Remain unchanged
4. Which of the following statement is true with reference to teeth in frog  
(a) The lower jaw is toothless  
(b) The upper jaw is toothless  
(c) Both lower and upper jaws are toothless  
(d) Both lower and upper jaws are toothed
5. Which of the following part is not a part of the small intestine of frog  
(a) Ileum (b) Jejunum  
(c) Duodenum (d) None of these
6. In frog, pancreas produces [CBSE PMT 1991]  
(a) Two digestive enzymes, one hormone  
(b) Three digestive enzymes, one hormone  
(c) Three digestive enzymes, two hormones  
(d) Three digestive enzymes, three hormones
7. Stomach of frog does not have  
(a) Fundic part (b) Cardiac part  
(c) Pyloric part (d) All of these
8. Contraction of sternohyal muscles during breathing in frog [CBSE PMT 1992]  
(a) Closes glottis  
(b) Opens the nostrils  
(c) Raises floor of oral cavity  
(d) Lowers floor of oral cavity
9. Pylangium in frog is found in [CBSE PMT 1990]  
(a) Atrium (b) Ventricle  
(c) Sinus venosus (d) Conus arteriosus
10. A spiral valve is present in  
(a) Sinus venosus of frog's heart  
(b) Right auricle of rabbit's heart  
(c) Pylangium of the conus arteriosus of frog's heart  
(d) Synangium of the conus arteriosus of frog's heart
11. Three chambered heart of frog is not as efficient as four-chambered human heart because [EAMCET 1999]  
(a) Heart muscles are not strong  
(b) It does not hold enough blood  
(c) Ventricle does not pump blood properly  
(d) Oxygenated and deoxygenated blood mix up
12. Velocity of conduction of nerve impulse in frog is [CBSE PMT 1991, 93]  
(a) Faster than sound (b) 30 metre per second  
(c) 300 metre per second (d) None of these
13. Which one of these are never present in frog's ovary  
(a) Oogonia (b) Corpus luteum  
(c) Ovarian follicles (d) Germinal epithelium
14. There is no gall bladder in  
(a) Rat (b) Horse  
(c) Whale (d) All of these

## Critical Thinking

### Objective Questions

1. Frog has [NCERT; AFMC 1991]  
(a) 4 fingers in hand and 5 toes in foot  
(b) 5 fingers in hand and 5 toes in foot  
(c) 5 fingers in hand and 4 toes in foot  
(d) 6 fingers in hand and 5 toes in foot
13. Which one of these are never present in frog's ovary  
(a) Oogonia (b) Corpus luteum  
(c) Ovarian follicles (d) Germinal epithelium
14. There is no gall bladder in  
(a) Rat (b) Horse  
(c) Whale (d) All of these

15. The clitellum is a distinct part in the body of earthworm, it is found in [NCERT]  
 (a) Segments 13 – 14 – 15 (b) Segments 14 – 15 – 16  
 (c) Segments 12 – 13 – 14 (d) Segments 15 – 16 – 17
16. Setae help in locomotion in earthworm but not uniformly present in all the segments. Select among the following that represents setae [NCERT]  
 (a) 1<sup>st</sup> segment (b) Last segment  
 (c) Clitellar segment (d) 20<sup>th</sup> – 22<sup>nd</sup> segment

## Answers

### Morphology of Frog

1	a	2	a	3	b	4	d	5	c
6	c	7	a	8	b	9	a	10	b
11	a	12	c	13	d	14	a	15	d
16	b	17	c	18	b	19	a	20	b
21	c	22	b	23	b	24	b	25	d
26	d	27	a	28	c	29	b	30	c
31	b	32	d	33	c	34	d	35	d
36	a	37	a	38	c	39	b	40	c
41	a	42	d	43	b	44	a	45	b
46	a	47	b	48	a	49	c	50	a
51	c	52	b	53	b	54	a	55	d
56	b	57	c	58	a	59	c	60	a
61	b	62	d	63	c	64	b	65	b
66	d	67	c	68	d	69	d	70	d
71	d	72	a	73	a	74	b	75	c
76	a	77	b	78	d	79	d		

### Morphology of Rat

1	d	2	a	3	a	4	b	5	c
6	b	7	a	8	b	9	d	10	b
11	d	12	b	13	c	14	a	15	c
16	b	17	b	18	b	19	d	20	a
21	d	22	b	23	a	24	d	25	d
26	d	27	a	28	b				

### Critical Thinking Questions

1	a	2	a	3	b	4	a	5	b
6	b	7	a	8	d	9	d	10	c
11	d	12	d	13	b	14	d	15	b
16	d								

## S Answers and Solutions

### Morphology of Frog

- (a) Anura is characterized by the absence of tail, also known as salientia, the Leaping animals
- (c) The scientific name of common toad is *Bufo melanostictus*
- (a) The elevated poison secreting glands or parotid glands are present behind each tympanum of *Bufo*
- (a) Being cold blooded or poikilothermous (the body temperature changes with environment) frogs undergo aestivation or 'summer sleep' in summer and hibernation or 'winter sleep' in winter
- (a) Croaking is a natural voice of frog which is heard more commonly during breeding season. Male frog croaks more loudly because it possesses two vocal sacs over its throat which act as resonators
- (b) In indirect development, the young ones do not resemble the adults. The young ones usually pass through one or more intermediate stages before obtaining the shape of the adults.
- (b) A pair of internal nares, in the form of two small opening are present on the roof of the buccal cavity lying outer to vomerine teeth
- (b) The mucous glands secrete a slimy fluid, the mucus, which makes the skin moist and slippery in nature.
- (d) During capacitation sperms undergo acrosomal reaction and release various chemicals contained in the acrosome. These chemicals are collectively called sperm lysin, which dissolve covering membrane of oocyte.
- (d) Just beneath the stratum germinativum there are present many scattered pigment cells (chromatophores) in the stratum spongiosum.
- (a) The skin of frog provides an extensive surface for the exchange of gases (cutaneous respiration).
- (b) Each frog's egg is surrounded by the vitelline membrane (secondary egg membrane) and many layers called tertiary egg membrane of adhesive jelly which were added as it passes through the oviduct or during fertilization
- (b) Bidder's canal is present in the kidney of male frog. It is helpful in the transfer of sperms from the vasa efferentia to water
- (d) The pyloric stomach is separated from the duodenum by a muscular construction, the pyloric constriction externally, which indicates the position of pyloric sphincter, which controls the entry of food into duodenum.
- (c) Frog is a positive pressure breather. It fills its lung by forcing air into them, for this, mouth has to be kept closed.
- (b) In frog, cutaneous respiration occurs in water, during hibernation and even aestivation
- (b) The lungs of frog are two delicate, elastic, pinkish, ovoid, thin walled hollow sacs lying on either side of the oesophagus

45. (b) In frog, the skin serves as an accessory organ of respiration because the skin of frog is thin and richly supplied with blood capillaries. It is kept moist by mucus and water
46. (a) In frog, the cutaneous respiration is always carried out. During winter sleep and summer sleep it is the only method of respiration in frog.
48. (a) RBCs of frog are nucleated, oval and biconvex and have haemoglobin (respiratory pigment).
49. (c) Two additional chambers connected to the heart of frog are sinus venosus and truncus arteriosus.
50. (a) Sinus venosus is a triangular chamber attached dorsally to heart formed by the union of three main vena cava.
52. (b) Amphibian heart is a three-chambered structure formed by two upper auricles and a single lower ventricle.
54. (a) Mesorchium is a thin mesentery that suspends testis from ventral anterior part of kidney
57. (c) Frog also possess well developed renal portal system. While it is absent in mammals
62. (d) The fenestra ovalis leads into auditory capsule.
63. (c) The main organs of excretion are paired mesonephric kidneys which are compact, dark red and bean like structure situated little posteriorly in the body cavity on both sides of vertebral column.
64. (b) Sclerotic is the outermost layer of eye ball which is fibrous in nature.
67. (c) Urinary bladder of frog is a transparent, highly distensible bilobed sac, attached to the ventral side of the cloaca.
69. (d) Embryologically columella auris of frog is homologous to stapes of mammals.
70. (d) In the tadpole, the end product of nitrogen metabolism is ammonia which is easily disposed off by diffusion in water. After metamorphosis, the frog excrete most of their nitrogen in the form of urea.
72. (a) Presence of external ear or pinna is a typical mammalian character
73. (a) Thin roof of cerebrum in frog is called pallium. This term is also used in reference to mantle of a mollusc or brachiopod.
74. (b) The number of spinal nerves is definite in a particular group of animals. In frog the number is ten pairs.
76. (a) Optic is second cranial nerve of frog, which carries impulse of sight from the eye to the brain and its nature is sensory.
14. (a) Diastema is a natural toothless space in mammals, in rat found between incisor and molar teeth
19. (d) Like other mammals rat possess closed and double circulation.
20. (a) The time interval between fertilization and birth (gestation period) is about 22 to 23 days.
21. (d) Fertilization is internal and takes place in the dilated uppermost portion of the fallopian tube
22. (b) The brain is protected by three membrane known as meninges
24. (d) Hepatic portal system is well-developed in mammals. The food-laden blood from various region of the digestive tract is collected by four vein –  
(i) lienogastric from stomach and spleen  
(ii) Duodenal from duodenum  
(iii) Anterior mesenteric from small intestine, caecum and colon.  
(iv) Posterior mesenteric from rectum.
26. (d) The functional kidney of higher vertebrates or amniotes is a metanephros.
27. (a) Graafian follicle is a matured ovarian follicle, which is found in the mammalian ovary.

### Critical Thinking Questions

1. (a) In frog, the fore limbs are shorter and stouter, end in four digits and the hind limbs are much larger and muscular than the forelimbs, end in five digits
2. (a) The cells of stratum malpighi of frog are continue growing and divide mitotically throughout life to form new layer being pushed towards the surface successively.
4. (a) The lower jaw of frog is toothless. Teeth are present on premaxillae, maxillae of upper jaw.
5. (b) Stomach is followed by a coiled small intestine made of a small anterior duodenum and much longer posterior ileum. Jejunum is absent in frog.
6. (b) In frog, pancreas is made up of lobules, connective tissue and islets of langerhans. The islets of Langerhans secrete a hormone known as insulin. The pancreatic juice contains three enzymes. The trypsin, amyllopsin and steapsin or lipase
7. (a) Stomach of frog comprises a large broader anterior part called cardiac stomach and a short narrower posterior part called pyloric stomach. Fundic stomach is absent.
8. (d) Throat is lowered and raised alternatively by sternohyal and petrohial muscles.
9. (d) Truncus arteriosus of frog is divided into a long basal thick walled conus arteriosus or pylangium and a short distal thin walled bulbous aorta or synangium.
10. (c) A large twisted spiral valve divides incompletely the cavity of pylangium into a left dorsal cavum pulmocutaneum and right ventral cavum aorticum.
13. (b) Corpus luteum, an endocrine structure, is formed in the mammalian ovary from ruptured Graafian follicle after ovulation.
14. (d) Gall bladder is absent in rat (also in whales, some artiodactyla and all perissodactyla).

### Morphology of Rat

1. (d) Most Important character of mammals is the presence of mammary glands (modified sweat glands).
3. (a) In male rat, a pair of testes is found in the scrotal sacs
4. (b) Rat is fossorial animal i.e. living in burrows.
5. (c) *Rattus norvegicus* is common brown rat.
6. (b) Each limb of rat is made up of proximal segment, the stylopodium, middle segment the zeugopodium and distal segment the autopodium.
9. (d) One pair of thoracic nipples, two pairs of axillary nipple, one pair of abdominal nipples and two pairs of inguinal nipples
12. (b) The dental formula of rat is  $\frac{1003}{1003} = 16$ .
13. (c) In haemoendothelial placenta, all the three uterine tissue barriers (foetal connective tissue and trophoblast) are absent with only one placental barrier. e.g. rabbit, rat and guinea pig.

# Morphology of Animals

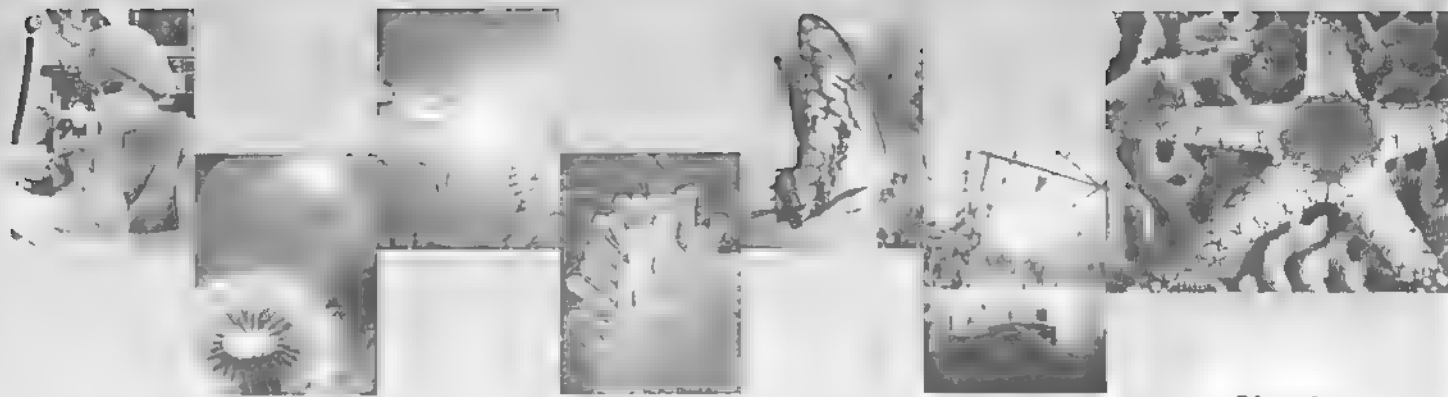
## ET Self Evaluation Test

1. During breeding season, nuptial pad is found in the thumb of  
(a) Male frog (b) Female frog  
(c) Both of these (d) None of these
2. The glands present in the skin of frog are  
[NCERT; AFMC 1993]  
(a) Sweat and mucous  
(b) Sweat and mammary  
(c) Mucous and poisonous  
(d) Sweat and sebaceous
3. The structure present in man but absent in frog is  
[NCERT; AFMC 2001]  
(a) Pancreas (b) Thyroid gland  
(c) Adrenal gland (d) Salivary gland
4. The epithelial lining of the alveoli of frog's lungs facing lung cavity is  
[CBSE PMT 1990]  
(a) Columnar and ciliated  
(b) Squamous and ciliated  
(c) Squamous and nonciliated  
(d) Columnar and nonciliated
5. RBCs of rat are  
(a) Small, round, nonnucleated and biconcave  
(b) Small, round, nonnucleated and biconvex  
(c) Small, oval, nonnucleated and biconcave  
(d) Small, round, nucleated and biconcave
6. The jaws, eye orbits and nasal chambers in frog are supplied by  
(a) Occipital arteries  
(b) Vertebral arteries  
(c) External carotid arteries  
(d) Internal carotid arteries
7. Which one is the correct statement in regard to frog  
[CBSE PMT 1993]  
(a) Fertilization occurs in uteri  
(b) Ova from ovary are shed into infundibuli, pass through oviducts and stored in uteri  
(c) Testes develop inside kidney, so that sperms are able to reach the urinogenital ducts  
(d) Male and female frogs are similar but gonads appear at the time of reproduction
8. Anterior abdominal vein in frog is formed by union of  
[CBSE PMT 1991; AMU (Med.) 2009]  
(a) Right and left pelvic veins  
(b) Right and left sciatic veins  
(c) Right and left femoral veins  
(d) Right and left dorsolumbar veins
9. Which of the following is true of hibernating gland in rat  
(a) It is gland formed during hibernation  
(b) It secretes digestive enzymes to metabolise fat  
(c) Its secretion regulate the body temperature during winter sleep  
(d) It is not a gland at all, but a multicellular adipose tissue
10. Glands of Swammerdam are related with  
(a) Spinal nerves of frog (b) Cranial nerves of frog  
(c) Endocrine system of frog (d) Alimentary canal of frog
11. Bidder's canal is meant for passage of [NCERT]  
(a) Ova (b) Urine  
(c) Sperms (d) All of these

## S Answers and Solutions

1	a	2	c	3	d	4	a	5	a
6	a	b	B	a	9	d	10	a	
11	c								

1. (a) Frog exhibit sexual dimorphism. Male and female are distinguishable externally only during breeding season when the male develop roughed nuptial pads on the bases of the thumb. Nuptial pads help male in holding female, a sexual embrace called amplexus
2. (c) Skin is soft, moist and slimy consists of epidermis and dermis. Mucous glands and poison glands are present in the dermis and their ducts open at the surface.
3. (d) Frog has no salivary glands
4. (a) Ciliated columnar epithelium comprises columnar cells which have cilia on free surface. This epithelium lines most of the respiratory tract and fallopian tubes.
5. (a) RBCs of rats are small round, nonnucleated and biconcave containing red coloured respiratory pigment namely haemoglobin
6. (a) The occipital artery in front supplies jaws, eye orbit and nasal chambers. It is a branch of occipito-vertebral artery
8. (a) The pelvic veins of both sides unite to form a median ventral or anterior abdominal vein. It receives blood from urinary bladder and ventral abdominal wall
9. (d) A fatty mass of pinkish colour, located in the region between the scapulae and neck of rat is often called hibernating gland.
10. (a) Glands of swammerdam are soft chalky masses of calcareous bodies found in the dorsal root ganglion of spinal nerve in frog. These form reserve supplies of calcium
11. (c) Bidder's canal is present in the kidney of male frog. It is helpful in the transfer of sperms from the vasa efferentia to water



## Chapter 3.1

# Cell : The Unit of Life

## Microscopy

Microscopy (Gk. *Micros* = small, *skopein* = to see) is practice of using microscopes for the study of finer details of small objects including cells and tissues. Microscope are instruments consisting of lenses (made of glass / Lithium fluoride / electromagnetic lens) which magnify and resolve small objects not visible to unaided eye for the study of their details. The term microscope was coined by **Faber** in 1625

**Magnification** : It is the degree of enlargement or the ratio of size of the object as seen in the microscope to its actual size

$$\text{Magnification} = \frac{\text{Size of the image with the instrument}}{\text{Size of the image with unaided eye}}$$

Magnification of a microscope is roughly equal to the multiple of magnifying power of objective lens and ocular lens (eye piece) e.g., if the magnification power of an ocular lens is 10X and of the objective is 40X, then the total magnifying power of a microscope is  $10 \times 40 = 400X$  (the magnification power of a microscope is represented by the symbol 'X').

**Resolving power** : It is the ability of a system to distinguish two close objects as two distinct objects. Its value is calculated by Abbe equation –

$$L_m = \frac{0.61\lambda}{NA}$$

Here,  $\lambda$  – is wavelength of used light, NA – Numerical Aperture, ( $NA = n \sin \theta$ )

Numerical aperture is multiple of refractive index of medium ( $n$ ) and  $\sin \theta$ , which is sine of angle subtended by optical axis and outer ray covered by objective. The value for best objective  $\sin 70^\circ = 0.94$

Resolving power of a light microscope ranges from  $0.2\mu m$  to  $0.4\mu m$  in blue light.

The resolving power of human eye is  $100\mu m$  or microns ( $0.1 mm$ ) This means that two points less than  $100\mu m$  apart appear as one point to our eyes.

Father of microscopy is *Leeuwenhoek*. He built first 270 X magnification microscope in 1672

## Types of microscopes

(1) **Simple microscope** : It is also known as magnifying glass and consists of a convergent lens.

*Leeuwenhoek* (1683) designed a primitive microscope and discovered cells with it. It was the first tool ever used to observe biological objects. Its magnification power was 14 – 42 times only, so it is considered as simple microscope.

(2) **Compound microscope or Light microscope** : The first compound microscope was assembled by *Zacharias Janssen* and *J. Janssen*, the Dutch spectacles maker in 1590. The compound microscope was prepared by *Kepler* and *Galileo* in 1611. However, it was not used for laboratory study. It is simplest, widely used microscope having three lens i.e., condensor, which collects the light rays and precisely focuses them on the objects; objective lens, which magnifies the image by three objective lenses, i.e., low power (10x), high power (45x) and oil immersion lenses

In a compound microscope an object can be magnified upto 1000 times and the magnification is independent of intensity of light, size of microscope and numerical aperture. The light microscope is also called *bright field* microscope because it forms the image when light is transmitted through the object.

(3) **Fluorescent microscope** : It was developed by *Coons* (1945). It is observed that when ultraviolet light is irradiated on certain chemical substances, they absorb it and emit visible light. These chemical substances are called fluoro-chromes. The fluorescent substances e.g., quinine sulphate, rhodamine and auramine are used to stain the cellular objects and these objects are easily visible as fluorescent areas when illuminated with ultraviolet light.

(4) **Polarizing microscope** : It was invented by *Tolbert*. In this microscope the plane polarised light is used as a source of illumination. Unlike the ordinary light, plane polarised light vibrates only in one direction and the cellular objects are easily visible as they appear bright against the dark ground. Polarizing microscope is helpful in studying the spindle fibres in the cells.

(5) **Ultraviolet microscope** : It was invented by *Caspersson*. In this microscope the source of illumination is ultraviolet radiations having shorter wavelengths (1500 Å – 3500 Å) as compared to ordinary visible light. In this microscope, the lenses are made of fluoride, lithium fluoride or quartz instead of glass.

Ultraviolet microscope is helpful in quantitative determination of all those cell components which absorb ultraviolet rays.

#### (6) Phase contrast microscope

(i) Discovered by Dutch man *Fredericke Zernicke* (1935)

(ii) Source of illumination is visible light.

(iii) It is used to study living cells and tissues without staining and effect of chemical and physical agents on the living cells.

(iv) It is also used to study spindle formation, pinocytosis, karyokinesis, cytokinesis etc.

(v) The demerit of this microscope is subcellular organelles smaller than  $0.2\mu$ , (like ribosomes, lysosomes, ER) cannot be visualised

#### (7) Interference microscope (*Morten et.al.*)

(i) It's principle is similar to that of the phase contrast microscope and gives / studies quantitative data.

(ii) Nomarski Interference contrast microscope is useful to study mitosis /cell components in living state

(iii) It gives better image of living structures. It is also used to measure thickness of the cell and determination of several light absorbing chemicals like nucleic acid, proteins, lipids etc.

#### (8) Dark field microscope

(i) *Zsigmondy* (1905) invented this microscope

(ii) It is based on the fact that light is scattered at boundaries between regions having different refractive index.

(iii) The object smaller than those seen with ordinary light microscope can be detected but can not be resolved.

(9) **Electron microscope** : This was developed by *M. Knoll* and *E. Ruska* (1931) in Germany. It is the best device to determine the ultrastructure of a cell organelle. It is a large sized instrument which has an internal vacuum, high voltage (50,000 – 1,00,000 volts), a cooling system, a fast beam of electrons (0.54 Å wavelength), a cathod filaments of tungsten and electromagnetic lens (which having a coil of wire enclosed in soft iron casing) for focusing. Ribosomes can be seen only in electron microscope.

Thus an electron microscope essentially comprises an electron gun and electron lenses. The electron gun is the source of electrons consisting of a heated tungsten filament. It is preferred because it can be heated upto 3000°C. The electron beam can be reflected by magnetic field. Therefore, a very powerful magnetic coil acts as lens. The focal length of the electromagnetic lenses change with the wavelength of illumination. Since the wavelength is controlled by the voltage, it should be controlled and made constant. Three types of magnetic lenses are used namely projector, objective and condenser. The magnetic field produced is concentrated by soft iron casing. When the filament is heated to incandescence, it emits electron. The electrons then move to positively charged anode. The entire microscope column operates under conditions of high vacuum. It is due to this fact that we can not observe living objects through an electron microscope (EM). For viewing objects under EM, ultrathin sections (20-100 nm thick) are prepared through an ultramicrotome. It was first developed by W.His.

Electron microscope can magnify the objects upto 2,00,000 times (now possible upto 2,50,000 – 4,00,000) and direct study of objects is possible on this microscope. The resolving power of electron microscope is 10 Å which is 100 times more than the light microscope. Study of living cells can not be done through this microscope because of high voltage, which is required to operate it, kills the living materials. Electron microscope are of two types :

(i) **Transmission electron microscope (TEM)** : It was the first microscope developed by *Ruska* (1932). It produces two dimensional images

Magnification of TEM is 1-3 lakh and resolving power is 2-10Å. Because of them transmission electron microscope has helped in the discovery of a number of small cell organelles e.g., ER, ribosomes, centrioles, microtubules etc. Detail structure of larger cell organelles could also be known only with the help of TEM. e.g., chloroplast (thylakoids), mitochondria (elementary particles, DNA), ribosomes etc.

(ii) **Scanning electron microscope (SEM)** : This microscope was invented by *Knoll* (1935).

It gives three dimensional image. The specimen to be studied is first super cooled (in liquid propane at -180°C) and dehydrated in alcohol (at -70°C). It is then coated with gold, platinum or some other metals for creating a reflecting surface for electrons. Magnification of SEM varies from 15 – 2,00,000. Resolution power is 5 – 20 nm



**(10) Advanced high power microscope**

(i) **Scanning probe microscope** : The microscope is capable of resolving the outer texture of the material to the minutest detail since it has the potential to image even a single atom. Magnification is upto 100 million.

(ii) **Scanning tunnelling microscope** : It has a tiny tungsten probe for moving over the surface of specimen. The microscope is used to detect defect in electrical conductors and computer chips.

(iii) **Atomic force microscope** : It has an extremely fine diamond probe for moving over the surface of biochemicals. Oscillations produced in the probe are changed into images by a computer.

The microscope is useful in viewing detailed structure of biological molecules, e.g., DNA, proteins, etc.

**Units of measurement used in microscopy**

1 micron ( $\mu$ ) =  $10^{-6}$  or one millionth

1 micrometer ( $\mu m$ ) =  $10^{-6} m$ ,  $10^{-4} cm$ ,  $10^{-3} mm$  = 1000 nm

1 Nanometer (nm) =  $10^{-9} m$ ,  $10^{-7} cm$ ,  $10^{-6} mm$ ,  $10^{-3} \mu m$  = 10 Å

1 Angstrom (Å) =  $10^{-10} m$ ,  $10^{-8} cm$ ,  $10^{-7} mm$ ,  $10^{-4} \mu m$ ,

1 Picometer (pm) =  $10^{-12} m$ ,  $10^{-3} nm$

1 Femtometer (fm) =  $10^{-15} m$ ,  $10^{-6} nm$

1 Attometer =  $10^{-18} m$ ,  $10^{-9} nm$

Common unit of measurement in Microscopy and cytology is nanometer while unit of measurement of cell is micron.

**Cytochemistry**

A number of dyes or stains are known to colour specific parts. Certain dyes can be used even in case of living materials. They are called vital stains, e.g., neutral red, methylene blue.

Fuelgen or Schiff's reaction was developed by Fuelgen and Rossenbeck (1924). Identification and localization of chemical compounds of a cell is studied in cytochemistry.

**Table : 3.1-1 Some important cytochemical stains**

Stain	Used for staining	Final colour
Acetocarmine	Chromosomes	Pink
Acid fuchsin	Cortex, cellular walls, mitochondria	Magenta
Aniline blue	Fungal hyphae	Blue
Basic fuchsin	Nucleus	Magenta red
Crystal violet	Bacteria	Violet
Eosin	Cytoplasm	Pink
Fuelgen's stain	DNA	Purple/Red
Hematoxyline	Nuclei, cell wall, cellulose	Violet
Iodine solution	Starch	Blue

Janus green	Fungi and mitochondria	Green
Methylene blue	Yeast and Golgi complex	Blue
Phloroglucinol + HCl	Lignin	Red
Ruthenium red	Pectin	Red
Safranin	Nuclei, lignified tissue	Red
Sudan- III or IV	Suberin, cutin, oil	Red
Sudan black	Fatty substance	Black
Toluidine blue	RNA	Blue
Cotton blue	Fungi	Violet

**Cell fractionation**

In isotonic medium cell components are separated, in two steps process.

**Homogenisation** : Cell products are separated in isotonic medium (0.25 M sucrose solution) either with the help of homogeniser or ultrasonic vibrations kept at 0 – 4°C. A homogenised cell is called homogenate.

**Differential centrifugation** : Homogenisation product is rotated (centrifuged) at different speeds. The sediment or pellete of each speed is collected. e.g., nuclei at  $1000 \times g$  ( $g$  = force of gravity) for 10 minutes, chloroplast and mitochondria at  $10,000 \times g$  for 15 minutes. The particles settle according to their sedimentation ratios. Sedimentation coefficient is expressed in svedberg unit 'S' related with molecular weight of the particles. For the detail study of mitochondria it is the best technique. 'S' is measured by analytical centrifugation.

The various cell organelles and macromolecules sediment in the following order

Nucleus → Chloroplast → Mitochondria → Ribosome → DNA → mRNA → tRNA

**Chromatography**

Discovered by Michael Tswett (1906). This technique is used to separate the molecules of different substances present together. Mixture of molecules is run over an adsorption medium. Chromatography may be following types

**Adsorption or Column chromatography** : The stationary phase consists of a column of charcoal, silica, alumina, calcium carbonate or magnesium oxide. The solution is made to percolate through this column when different chemicals get absorbed at various levels. The technique is useful for separation of tissue lipids.

**Thin layer chromatography (TLC)** : The stationary phase consists of a thin plate of cellulose powder or alumina. As a few drops of mixture are poured over it, the different chemicals spread to different distances. The method is useful in separation of amino acids, nucleotides and other low molecular weight products.

**Paper chromatography** : A paste of mixture is applied near one end of a chromatographic paper (or Whatman 1). The lower end below the paste is dipped in a solvent. As the solvent rises in chromatographic paper, the different chemicals of the mixture spread to different distances. The paper can be rotated to obtain two dimensional chromatogram.

Types . (a) Ascending (b) Descending (c) 2-D chromatography.

**Ion exchange chromatography** : Beads of cellulose and other materials having negative and positive charges are placed in a column. The mixture (mobile phase) is poured over the column. As the mixture passes through the column, its constituents separate according to their charges. The technique is used in purification of insulin, plasma fractionation and separation of proteins.

**Gel fractionation / Gel filtration chromatography (Molecular sieve chromatography)** : The stationary phase consists of gel forming hydrophilic beads which contain pores, e.g., sephadex (cross-linked dextran). As the mixture is poured over the gel, larger molecules pass out unimpeded while small molecules are trapped in the pores. The technique is used in separation of proteins. It is also employed in determining their molecular weight by calibrating the column with proteins of known molecular weight

**Affinity chromatography** : Stationary phase consists of column of ligands (molecules that bind to other specific molecules at particular sites).

Mixture is allowed to pass through the column. Chemical linkages are established between ligands and their specific chemicals. Others pass out of the column. The technique is used in separation of enzymes, immunoglobulins, mRNA, etc.

### Electrophoresis

It is another technique of separation in which particles of different charges and sizes are separated under the influence of electric field. e.g., nucleic acids, proteins, amino acids, nucleotides can be separated by this method. The technique was discovered by Russian physicist Alexander Reuss in 1807.

### Autoradiography

It is a technique of studying the route of chemicals in chemical reactions taking place inside the cell and organisms with the help of radioactive isotope. e.g.,  $^{14}\text{C}$ ,  $^3\text{H}$ ,  $^{32}\text{P}$ .

In this technique the radioisotopes are incorporated into the precursor molecule. Then the labelled precursor molecules introduced into the cells and their path is followed with the help of their radiations.

Radioactive precursors emit radiations and their position in the cell is located by bringing the cell in contact with a photographic plate or film.

$^{32}\text{P}$  and  $^{14}\text{C}$  are used for the study of nucleic acids and photosynthesis (Melvin Calvin) respectively.

### Radioisotope or Tracer technique

They are unstable isotopes which function like normal elements but emit positive or negative particles, e.g.,  $^3\text{H}$  (Tritium),  $^{14}\text{C}$  (Carbon),  $^{32}\text{P}$  (Phosphorus),  $^{35}\text{S}$  (Sulphur),  $^{42}\text{K}$  (Potassium),  $^{131}\text{I}$  (Iodine). Radioactivity is recorded in different parts by Geiger counter or scintillation counter or autoradiography to know regions of use and transport. The tracers have been used for knowing pathway of mineral transport (Stout and Hoagland, 1939), organic solute transport (Vernon and Aronoff, 1952), carbon assimilation (Calvin, 1955)

Where radioactive elements are not available, heavy isotopes are used, e.g.,  $^{15}\text{N}$ ,  $^{18}\text{O}$ . Their fate is recorded by mass spectroscopy and density gradient centrifugation. Meselson and Stahl (1958) studied DNA replication and Ruben *et al* (1941) evolution of oxygen (photolysis of water) in photosynthesis by using heavy isotopes.

### X-ray crystallography

It was developed by the Bragg (1913). They can be used as a tool for determining the arrangement of atoms in various biological molecules.

By using this technique Wilkins *et al.*, 1953 found out details of the DNA molecule for which he was also awarded Nobel Prize along with Watson and Crick in 1962. Kendrew, 1957 by using the same technique studied the molecules of myoglobin.

### Cell as a unit of life

**Cytology** (Gk Kytos = cell ; logos = study) : It is the branch of biology, which comprises the study of cell structure and function. "Cell is the structural and functional unit of all living beings". Study of metabolic aspects of cell components is called cell biology.

Robert Hooke (1665) discovered hollow cavities (empty boxes) like compartments in a very thin slice of cork (cell wall) under his microscope. He wrote a book "Micrographia" and coined the term *cellula*, which was later changed into cell. Grew and Malpighi also observed small structures in slice of plants and animals. Leeuwenhoek was the first to see free cells and called them "wild animalcules" and published a book "The secret of nature". He observed bacteria, protozoa, RBCs, sperms, etc. under his microscope.

**Cell theory** : H.J. Dutrochet (1824) a French worker gave the idea of cell theory.

The actual credit for cell theory goes to two German scientists, a Botanist M.J. Schleiden (1838) and a Zoologist T. Schwann (1839). They gave the concept "all living organisms are composed of cell". Schleiden and Schwann both supported the theory of "spontaneous generation". They also mentioned that "the new cell arises from nucleus by budding".

**Exceptions to the cell theory** : Viruses, viroids and prions are an exception to the cell theory as they are obligate parasites (sub-cellular in nature).

**Modification of cell theory** : Modification of cell theory was done by Rudolf Virchow (1855). He proposed the "law of cell lineage" which states that cell originates from pre-existing cells. i.e., (*omnis cellula-e-cellula*). It is also called "cell principle" or "cell doctrine". It states :

- (1) Life exists only in cells.
- (2) Membrane bound cell organelles of the protoplasm do not survive alone or outside the protoplasm
- (3) Cells never arise *de novo*. The new cells are like the parent cell in all respect.
- (4) All cells have similar fundamental structure and metabolic reactions.
- (5) Cells display homeostasis and remain alive

(6) Genetic information is stored in DNA and expressed within the cells

(7) DNA controls structure and working of a cell.

**The cell as a self contained unit :** Autonomy of a cell is believed due to presence of DNA and its expressibility, otherwise, cell components have different shape and function. It has two positions.

(1) **Autonomy in unicellular organisms :** Unicellular organisms leads to a totally independent life due to different shape, size and role of different organelles shows division of labour. All these display homeostasis. Unicellular organisms are more active due to large surface volume ratio

(2) **Autonomy in multicellular organisms :** In multicellular organisms life activities are displayed by each of the cells independently. Multicellular organisms have one thing advantage over unicellular organisms is division of labour.

**Cellular totipotency :** Totipotency was suggested by *Haberlandt* (1902). When cells have tendency or ability to divide and redivide the condition of the cell is called totipotent and this phenomenon is called *totipotency*. *Steward et al.* showed the phenomenon of cellular totipotency in phloem tissue of carrot.

**Surface volume ratio :** Metabolically active cells are small, as small cells have higher nucleocytoplasmic ratio for better control and higher surface volume ratio for quicker exchange of materials between the cell and its outside environment. Larger cells have lower surface volume ratio as well as lower nucleocytoplasmic ratio. Surface volume ratio decreases if cell size increases

**Table : 3.1-2 Differences between plant and animal cell**

Plant cell	Animal cell
Cell wall present.	Cell wall absent.
Nucleus usually lies near periphery due to vacuole	Nucleus present near the centre
Centrosome is usually absent from higher plant cells, except lower motile cells.	Usually centrosome is present that helps in formation of spindle fibres.
Plastids are present, except fungi.	Plastids are absent.
Mitochondria is generally spherical or oval in shape	Generally tubular in shape
Single large central vacuole is present	Many vacuoles occurs, which are smaller in size
Cytoplasm during cell division usually divides by cell plate method	Cytoplasm divides by furrowing or cleavage method
Plant cells are capable of forming all the amino acids, coenzymes and vitamins	Animal cells cannot form all the amino acids, coenzymes and vitamins
There is no contractile vacuole	Contractile vacuole may occur to pump excess water
Spindle formed during cell division is anastral	Spindle formed during cell division are amphiastral
Lysosomes present in less number	Lysosomes present in more number

## Types of cells

Chatton gave the term prokaryote and eukaryote. Depending upon the nature of nucleus, cells are classified. Incipient nucleus is present in prokaryotes, where as in eukaryotes well organised nucleus is present.

**Table : 3.1-3 Differences between prokaryotic and eukaryotic cell**

Prokaryotic cell	Eukaryotic cell
It is a single membrane system	It is a double membrane system.
Cell wall surrounds the plasma membrane	Cell wall surrounds the plasma membrane in some protists, most fungi and all plant cell. Animal cell lacks it
Cell wall is composed of peptidoglycans. Strengthening material is murein.	It is composed of polysaccharide Strengthening material is chitin in fungi and cellulose in other plants.
Cell membrane bears respiratory enzymes	It lacks respiratory enzymes
Cytoplasm lacks cell organelles e.g., Mitochondria, ER, Golgi body etc	Cytoplasm contains various cell organelles.
Ribosomes are only 70 S type	Ribosomes are both 80 S and 70 S type
There are no streaming movements of cytoplasm.	Cytoplasm show streaming movements
Nuclear material is not enclosed by nuclear envelope and lies directly in cytoplasm. It is called nucleoid	It is enveloped by nuclear envelope. Nucleus is distinct from cytoplasm
DNA is circular and not associated with histone proteins.	Nuclear DNA is linear and associated with histone proteins. extranuclear DNA is circular and histone protein free.
Sexual reproduction absent but parasexuality present.	Sexual reproduction is present
Cell division mostly amitotic.	Cell division is typically mitotic

**Mesokaryon :** Dodge gave the term 'Mesokaryon' for dinoflagellates. These are intermediate type of cell organisation in dinophyceae of algae. In mesokaryotic there is present a true or eukaryotic nucleus with definite nuclear membrane and chromosomes.

## Cell wall

**Discovery :** It was first discovered by *Robert Hooke* in 1665 in Cork. Cell wall is the outer most, rigid, protective, non living and supportive layer found in all the plant cells, bacteria, cyanobacteria and some protists. It is not found in animal cells.

**Chemical composition :** Mainly cell wall consists of two parts, matrix and cellulosic fibres (microfibrils). Matrix consists of hemicellulose, pectin, glycoproteins, lipids and water. In most of the plants cell wall is made up of cellulose  $(C_6H_{10}O_5)_n$ , a polymer made-up of unbranched chain of glucose molecule linked by  $\beta$  1-4 glycosidic bond. About 100 molecules of cellulose form a micelle, about 20 micelle form a microfibril and approx. 250 microfibril form a fibril.

The cell wall of bacteria and the inner layer of blue green algae is made-up mucopolysaccharide. It is a polymer of two amino sugars namely N-acetyl glucosamine (NAG) and N-acetyl muramic acid (NAM) held alternately in  $\beta$ -1,4- linkage. In higher fungi, the cell wall is made up of chitin, polymer of glucosamine.

**Structure :** Cell wall consists of middle lamella, primary wall, secondary wall, tertiary wall.

(1) **Middle lamella :** Middle lamella is the outermost region which functions as a common cementing layer between two cells. It is absent on the outer free surface. It ruptures to create intercellular spaces. Middle lamella is formed of calcium and magnesium pectate. Calcium pectate is main component of middle lamella. Fruit softening is due to gelatinisation of pectic compounds of middle lamella. Pectin is used as commercial jellying agent, which is present outside the primary wall

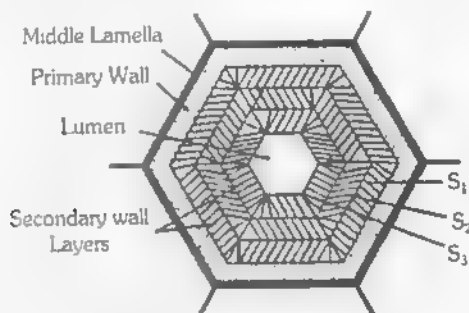


Fig : 3.1-1 T. S. of A Plant cell wall

(2) **Primary wall :** A young plant cell forms a single layer of wall material. This layer is known as the primary cell wall. The primary wall is thin, elastic and capable of expansion in a growing cell. It grows by intussusception. Meristematic and parenchymatous cells have primary cell wall only. The cells of leaves and fruits too have only primary wall. It has more hemicellulose and less cellulose

(3) **Secondary wall :** In mature cell, more layers of wall material are added internal to the primary wall. These are called the secondary cell wall. Growth by addition of new wall material on the primary wall is called accretion. It has more cellulose and less hemicellulose. The secondary wall is thick and rigid. It usually consists of three layers, which are often named  $S_1$ ,  $S_2$  and  $S_3$ . It is found in collenchyma and sclerenchyma cells, xylem vessels.

(4) **Tertiary wall :** Sometimes tertiary wall is laid down on secondary wall, e.g., tracheids of gymnosperms. It is composed of cellulose and xylan.

**Origin :** A cell wall is organised at telophase stage of cell division. The plane and place of cell wall is determined by the microtubules. Fragments of ER and vesicles of golgi body aligned at the equator, called as phragmoplast, later which forms the cell plate. The synthesis of cellulose takes place by the help of enzyme cellulase synthetase present in the plasma membrane. The cell plate forms the cell wall. Beside these, different materials are deposited as

(i) **Lignin :** It is special type of polysaccharide which deposits mainly in xylem cells and makes them hard and lignified. Due to its deposition xylem tracheids take up different forms, e.g., annular thickening, spiral thickening, scalariform thickening.

(ii) **Cutin :** It is a wax-like fatty substance. It is deposited on the epidermal cells in the form of cuticle which reduces loss of water. Cuticle is very thick in xerophytes, thin in mesophytes and absent in hydrophytes.

(iii) **Suberin :** It is a complicated mixture of fatty acids deposited on cork cells. Suberin is impermeable to water.

(iv) **Mucilage :** Some cells are slippery to touch due to secretion of mucilage, e.g., blue-green algae. The cells can withstand extremes of temperature, i.e., very low or very high.

(v) **Silica :** In some cases sand or silica particles are deposited which give a rough touch, e.g., *Equisetum* and *Saccharum munja*.

In family Moraceae, Urticaceae, Cucurbitaceae and Acanthaceae, Ca oxalate and Ca carbonate crystals are deposited.

#### Growth of cell wall

(1) **By intussusception :** As the cell wall stretches in one or more directions, new cell wall material secreted by protoplasm gets embedded within the original wall.

(2) **By apposition :** In this method new cell wall material secreted by protoplasm is deposited by definite thin plates one after the other

**Thickenings of cell wall :** In many secondary walls specially those of xylem the cell wall becomes hard and thick due to the deposition of lignin. With the increasing amount of lignin, deposition protoplasm is lost. First the lignin is deposited in middle lamella and primary wall and later on in secondary wall.

**Pits :** Secondary walls may have irregular thickenings at some places and these places are called pits. Pits are of five types :

(1) **Simple pit :** In which pit chamber is uniform in diameter.

(2) **Bordered pit :** In which pit chamber is flask shaped in tracheids of gymnosperm and vessels of angiosperms.

(3) **Blind pit :** A pit without any corresponding pit on the adjacent wall is called blind pit.

(4) **Half bordered pit :** A pit with half border and the rest half with a simple pit.

(5) **Aspirated pit :** It is a non-functional pit in which the pit aperture is blocked permanently by torus.

**Plasmodesmata :** Tangle (1879) first of all discovered them and were studied elaborately by Strasburger (1901). A number of plasmodesmata or cytoplasmic strands are present in pit through which the cytoplasm of one cell is in contact with another. Endoplasmic reticulum plays a role in origin of plasmodesmata.

#### Functions of cell wall

(1) It maintains shape of the plant cells and protect the cells from mechanical injury.

(2) It wards off the attacks of pathogens (viruses, bacteria, fungi, protozoans)

(3) It provides mechanical support against gravity. It is due to the rigid cell wall that the aerial parts of the plants are able to keep erect and expose their leaves to sunlight.

(4) The cell wall prevents undue expansion of the cell when water enters by osmosis to compensate for the lack of contractile vacuole. This prevents bursting of cells.

(5) Though permeable, the cell wall plays some regulatory role on the passage of materials into and out of the cell.

(6) Pores in the cell walls permit plasmodesmata to link up all the protoplasts into a system called symplast (symplasm).

(7) Cell wall and intercellular spaces constitute a nonliving component of plant body known as apoplast.

### Plasma membrane

Every living cell is externally covered by a thin transparent electron microscopic, elastic regenerative and selective permeable membrane called plasma membrane. It is quasifluid in nature. Membranes also occur inside the cells. They are collectively called biomembranes. The term cell membrane was given by C. Nageli and C. Cramer (1855) for outer membrane covering of the protoplast. It was replaced by the term plasmalemma by Pflöger (1931).

**Chemical composition :** Proteins lipoprotein (Lipid + Protein) are the major component forming 60% of the plasma membrane. Proteins provide mechanical strength and responsible for transportation of different substances. Proteins also act as enzyme. Lipids account may 28%-79% depending upon the type of cell and organism involved (In humans, myelin 79%). The lipids of plasma membrane are of three types namely **phospholipids**, **glycolipids** and **sterols**. The sterol found in the membrane may be cholesterol (Animals), phytosterol (Plants) or ergosterol (Microorganisms).

Carbohydrates form 2%-10%. Oligosaccharides are the main carbohydrates present in plasma membrane. The carbohydrates of plasma membrane are covalently linked to both lipid and protein components.

**Ultrastructure :** Under electron microscope the plasma membrane appears three layered, i.e., trilaminar or tripartite. One optically light layer is of lipid and on both sides two optically dense protein layers are present.

**Molecular structure and different models :** Several models have been proposed to explain the structure and function of the plasma membrane.

(1) **Overton's model :** It suggests that the plasma membrane is composed of a thin lipid single layer.

(2) **Sandwich model :** It was proposed by Davson and Danielli (1935). According to this model the light biomolecular lipid layer is sandwiched between two dense protein layers (globular  $\alpha$  type protein). This model was also said to be unit membrane hypothesis.

(3) **Robertson's unit membrane model :** It states that all cytoplasmic membranes have a similar structure of three layers with an electron transparent phospholipid bilayer being sandwiched between two electron dense layer of proteins (extended or  $\beta$  type protein).

Its thickness is about 75 Å with a central lipid layer of 35 Å thick and two peripheral protein layers of 20 Å thick.

(4) **Fluid mosaic model :** The most important and widely accepted latest model for plasma membrane was given by Singer and Nicolson in 1972. According to them it is "protein iceberg in a sea of lipids."

According to this model, the cell membrane consists of a highly viscous fluid matrix of two layers of phospholipid molecules. Protein molecules occur as separate particles asymmetrical arranged in a mosaic pattern.

Some of these are loosely bound at the polar surfaces of lipid layers, called peripheral or extrinsic proteins. Others penetrate deeply into the lipid layer called integral or intrinsic proteins. Some of the integral proteins penetrate through the phospholipid layers and project on both the surface. These are called trans membrane or tunnel proteins (glycophorins). Singly or in groups, they function as channels for passage of water ions and other solutes.

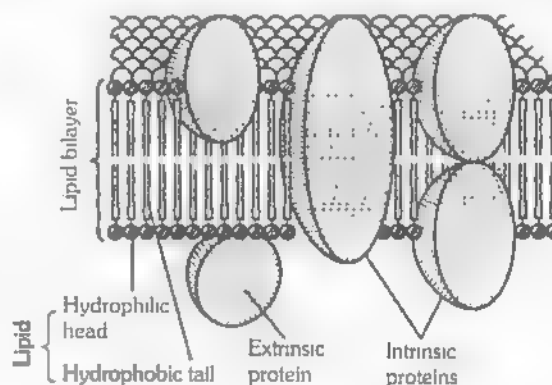


Fig : 3.1-2 Fluid-mosaic model of the plasma membrane structure

The carbohydrates occur only at the outer surface of the membrane. Their molecules are covalently linked to the polar heads of some lipid molecules (forming glycolipids) and most of the proteins exposed at outer surface (forming glycoproteins). Through glycoproteins, bacteria recognise each other. e.g., female bacteria are recognised by male bacteria.

### Modification of plasma membrane

(1) **Microvilli :** They are finger like evaginations of 0.1  $\mu\text{m}$  diameter, engaged in absorption. e.g., intestinal cells, hepatic cells, mesothelial cells. The surface having microvilli is called striated border or brush border.

(2) **Lomasomes :** They are plasmalemma foldings found in fungal cells. These were reported by Moore and Maclean.

(3) **Mesosomes** : It serves as site for cellular respiration in prokaryotes

(4) **Tight junctions or (Zonulae occludens)** : Plasma membrane of two adjacent cells are fused at a series of points with a network of ridges or sealing strands. e.g., capillaries, brain cells collecting tubules etc

(5) **Desmosomes** : Concerned with cell adherence.

(6) **Transomesomes** : It is found in follicular cells of ovary of birds and have triple unit membrane. First reported by Press (1964).

#### Functions

(1) It not only provides mechanical strength but also acts as a protective layer

(2) Plasma membrane is responsible for the transportation of materials, molecules, ions etc

(3) It helps in osmoregulation

(4) Diffusion of gases ( $O_2$  and  $CO_2$ ) take place through plasma membrane by simple and facilitated diffusion.

(5) Water as well as some solute molecules and ion pass through membrane pores: pores are always bordered by channel proteins.

#### Membrane transport

It is passage of metabolites, by-products and biochemicals across biomembrane. Membrane transport occurs through four methods—passive, facilitated, active and bulk. Size of the particles passing through plasmalemma is generally 1 – 15 Å.

**Passive transport** : No energy spent. Passive transport occurs through diffusion and osmosis.

(1) **Diffusion** : It is movement of particles from the region of their higher concentration or electrochemical potential to the region of their lower concentration or electrochemical potential. Electrochemical potential operates in case of charged particles like ions. Simple diffusion does not require carrier molecules.

(2) **Osmosis** : It is diffusion of water across a semipermeable membrane that occurs under the influence of an osmotically active solution

**Mechanism of passive transport** : Passive transport can continue to occur if the absorbed solute is immobilised. Cations have a tendency to passively pass from electropositive to electronegative side. While anions can pass from electronegative to electropositive side. There are two modes of passive transport.

(1) **Lipid matrix permeability** : Lipid soluble substances pass through the cell membrane according to their solubility and concentration gradient, e.g., triethyl citrate, ethyl alcohol, methane.

(2) **Hydrophilic membrane channels** : They are narrow channels formed in the membrane by tunnel proteins. The channels make the membrane semipermeable. Water passes inwardly or outwardly from a cell through these channels according to osmotic gradients.  $CO_2$  and  $O_2$  also diffuse through these channels as per their concentration gradients.

**Facilitated transport or Facilitated diffusion** : It is passage of substances along the concentration gradient without expenditure of energy that occurs with the help of special permeating substances called permeases. Permeases form pathways for movement of certain substances without involving any expenditure of energy. Facilitated transport occurs in case of some sugars, amino acids and nucleotides.

**Active transport** : It occurs with the help of energy, usually against concentration gradient. For this, cell membranes possess carriers and gated channels. At times certain substances are transported alongwith the ones requiring active transport. The latter phenomenon called cotransport.

(1) **Carrier particles or Proteins** : They are integral protein particles which have affinity for specific solutes. A solute particles combines with a carrier to form carrier solute complex. The latter undergoes conformational change in such a way as to transport the solute to the inner side where it is released into cytoplasm.

(2) **Gated channels** : The channels are opened by either change in electrical potential or specific substances, e.g., Calcium channels.

Active transport systems are also called pumps. The pumps operate with the help of ATP.  $K^+ - H^+$  exchange pump occurs in guard cells.  $Na^+ - K^+$  exchange pump operates across many animal membranes.

Active transport of one substance is often accompanied by permeation of other substances. The phenomenon is called secondary active transport. It is of two main types, cotransport (e.g., glucose and some amino acids alongwith inward pushing of excess  $Na^+$ ) and counter-transport ( $Ca^{2+}$  and  $H^+$  movement outwardly as excess  $Na^+$  passes inwardly).

**Bulk transport** : It is transport of large quantities of micromolecules, macromolecules and food particles through the membrane. It is accompanied by formation of transport or carrier vesicles. The latter are endocytotic and perform bulk transport inwardly. The phenomenon is called **endocytosis**. Endocytosis is of two types, pinocytosis and phagocytosis. Exocytic vesicles perform bulk transport outwardly. It is called exocytosis. Exocytosis performs secretion, excretion and ephagy

(1) **Pinocytosis** : (Lewis, 1931). It is bulk intake of fluid, ions and molecules through development of small endocytotic vesicles of 100 – 200 nm in diameter. ATP,  $Ca^{2+}$ , fibrillar protein clathrin and contractile protein actin are required. Fluid-phase pinocytosis is also called cell drinking. After coming in contact with specific substance, the area of plasma membrane having adsorptive sites, invaginates and forms vesicle. The vesicle separates. It is called **pinosome**. Pinosome may burst in cytosol, come in contact with tonoplast and pass its contents into vacuole, form digestive vacuole with lysosome or deliver its contents to Golgi apparatus when it is called **receptosome**

(2) **Phagocytosis** : (Metchnikoff, 1883). It is cell eating or ingestion of large particles by living cells, e.g., white blood corpuscles (neutrophils, monocytes), Kupffer's cells of liver, reticular cells of spleen, histiocytes of connective tissues, macrophages, Amoeba and some other protists, feeding cells of sponges and coelenterates. Plasma membrane has receptors. As soon as the food particle comes in contact with the receptor site, the edges of the latter evaginate, form a vesicle which pinches off as phagosome.

One or more lysosomes fuse with a phagosome, form digestive vacuole or food vacuole. Digestion occurs inside the vacuole. The digested substances diffuse out, while the residual vacuole passes out, comes in contact with plasma membrane for throwing out its contents through **exocytosis** or ephagy.

### Protoplasm (Proto = first, plasm = fluid)

Protoplasm is a complex, granular, elastic, viscous and colourless substance. It is selectively or differentially permeable. It is considered as "Polyphasic colloidal system".

#### Discoveries

- (1) J. Huxley defined it as "physical basis of life".
- (2) Dujardin (1835) discovered it and called them "sarcode".
- (3) Purkinje (1837) renamed it as "Protoplasm".
- (4) Hugo Von Mohl (1844) gave the significance of it.
- (5) Max Schultz (1861) gave the protoplasmic theory for plants.
- (6) Fischer (1894) and Hardy (1899) showed its colloidal nature.
- (7) Altman (1893) suggested protoplasm as granular.

**Table : 3.1-4 Chemically composition**

Water	75 - 85%	Carbon	20%
Proteins	10 - 25%	Oxygen	62%
Lipids	2 - 3%	Hydrogen	10%
Inorganic materials	1%	Nitrogen	3%
Trace elements 5% (Ca, P, Cl, S, K, Na, Mg, I, Fe etc.)			

Maximum water content in protoplasm is found in hydrophytes, i.e., 95% where as minimum in seeds, spores (dormant organs) i.e., 10 - 15%. In animals water is less (about 65%) and proteins are more (about 15%).

#### Theories regarding nature of protoplasm

Following theories have been put forth regarding the nature of protoplasm

- (1) **Reticular theory** : Protoplasm possesses a delicate reticular structure. (by Heitzman)
- (2) **Granular theory** : Protoplasm consists of numerous minute granules (by Altman).
- (3) **Fibrillar theory** : Protoplasm is formed of fibres and these are proteinous nature. (by Flemming)
- (4) **Alveolar theory** : It consists of droplets of alveoli or minute bubbles resembling foams of emulsion (by Butschil).
- (5) **Colloidal theory** : Protoplasm is a polyphasic colloidal system (by Fisher & Hardy)

(6) **Sol  $\leftrightarrow$  gel theory** : Protoplasm is a colloidal solution consists of dispersion and dispersed phase. It exist in two state i.e., **sol** state (more  $H_2O$ ) and **gel** state (less  $H_2O$ ). This theory was proposed by Hyman.

(7) **Crystallo Colloidal theory** : Protoplasm is crystal, polyphasic, colloidal solution made of various inorganic substances like protein, carbohydrates and fats. This theory was proposed by Kolliker. It is most advanced and accepted theory of protoplasm.

#### Properties of protoplasm

(1) **Cyclosis movement** : These are shown by protoplasm. These are of two types.

**Rotation** : In one direction, either clockwise or anticlockwise e.g., *Hydrilla*, *Vallisneria*. Found only in eukaryotes

**Circulation** : Multidirectional movements around vacuole e.g., *Tradescantia*

(2) It shows stimulation or irritability, Sol-gel transformation and Brownian movements

(3) It is highly viscous and coagulates at  $60^\circ C$  or above or if treated with concentrated acids or bases.

(4) It's **pH** is on acidic side, but different vital activities occur at neutral **pH** which is considered as 7, injury decreases the pH of the cell (i.e., 5.2 - 5.5) and if it remains for a long time, the cell dies

**Protoplast** : A term coined by Hanstein (1880) include all the living constituents of the protoplasm viz. nucleus, cytoplasm and plasmalemma. It is a simply organized mass of protoplasm bounded by cell membrane with no cell wall

### Cytoplasm

The substance occurring around the nucleus and inside the plasma membrane containing various organelles and inclusions is called cytoplasm

(1) The cytoplasm is a semisolid, jelly - like material It consists of an aqueous, structureless ground substance called cytoplasmic matrix or hyaloplasm or cytosol

(2) It forms about half of the cell's volume and about 90% of it is water.

(3) It contains ions, biomolecules, such as sugar, amino acid, nucleotide, tRNA, enzyme, vitamins, etc

(4) The cytosol also contains storage products such as glycogen/starch, fats and proteins in colloidal state

(5) It also forms crystallo - colloidal system

(6) Cytomatrix is differentiated into ectoplasm or plasmagel (outer) and endoplasm or plasmasol (inner)

(7) Cytomatrix is three dimensional structure appear like a network of fine threads and these threads are called microfilaments (now called actin filaments or microtrabecular lattice) and it is believed to be a part of cytoskeleton. It also contains microtubules and intermediate cytoplasmic filaments



(8) Hyaloplasm contains metabolically inactive products or cell inclusions called deutoplast or metaplasts.

(9) Cytoplasmic organelles are plastid, lysosome, sphaerosome, peroxisome, glyoxysomes, mitochondria, ribosome, centrosome, flagellum or cilia etc.

(10) The movement of cytoplasm is termed as cyclosis (absent in plant cells).

## Mitochondria

Mitochondria (Gk. *Mito* = thread ; *chondrion* = granule) are semi autonomous having hollow sac like structures present in all eukaryotes except mature RBCs of mammals and sieve tubes of phloem. Mesosomes of prokaryotes (bacteria) is analogous to mitochondrion in eukaryotes

Mitochondria are also called chondriosome, chondrioplast, plasmosomes, plastosomes and plastochondrione.

### Discoveries

(1) These were first observed in striated muscles (Voluntary) of insects as granules by Kolliker (1850), he called them "sarcosomes".

(2) Flemming (1882) called them "fila" for thread like structure

(3) Altman (1890) called them "bioplast".

(4) C. Benda (1897) gave the term mitochondria.

(5) F. Meves (1904) observed mitochondria in plant (Nymphaea).

(6) Michaelis (1898) demonstrated that mitochondria play a significant role in respiration.

(7) Bensley and Hoerr (1934) isolated mitochondria from liver cells.

(8) Seekevitz called them "Power house of the cell".

(9) Nass and Afzelius (1965) observed first DNA in mitochondria.

**Number of mitochondria :** Presence of mitochondria depends upon the metabolic activity of the cell. Higher is the metabolic activity, higher is the number e.g., in germinating seeds.

(1) Minimum number of mitochondria is one in *Microasterias*, *Trypanosoma*, *Chlorella*, *Chlamydomonas* (green alga) and *Micromonas*. Maximum numbers are found (upto 500000) in flight muscle cell, (upto 50000) in giant *Amoeba* called *Chaos - Chaos*. These are 25 in human sperm, 300 - 400 in kidney cells and 1000 - 1600 in liver cells.

(2) Mitochondria of a cell are collectively called chondriome

**Size of mitochondria :** Average size is 0.5-1.00  $\mu\text{m}$  and length upto 1 - 10  $\mu\text{m}$ . Smallest sized mitochondria in yeast cells ( $1\mu\text{m}^3$ ) and largest sized are found in oocytes of *Rana pipiens* and are 20 - 40  $\mu\text{m}$ .

**Ultrastructure :** Mitochondria is bounded by two unit membranes separated by perimitochondrial space (6 - 10nm wide). The outer membrane is specially permeable because of presence of integral proteins called porins. The inner membrane is selective permeable. The inner membrane is folded or convoluted to form mitochondrial crests. In animals these are called cristae and in plants these folding are called tubuli or microvilli

The matrix facing face is called 'M' face and face towards perimitochondrial space is called 'C' face. The 'M' face have some small stalked particles called oxysomes or  $F_1$  particle or elementary particle or Rackers particle or Fernandez - Moran Particles ( $10^4$ - $10^5$  per mitochondria). Each particle is made up of base, stalk and head and is about 10nm in length.

Oxysomes have ATPase enzyme molecule (Packer, 1967) and therefore, responsible for ATP synthesis. The reaction of ATP formation is endergonic. These elementary particles are also called  $F_0 - F_1$  particles. The  $F_1$  particle is made up of five types of subunits namely  $\alpha, \beta, \gamma, \delta$  and  $\epsilon$ . of these  $\alpha$  is heaviest and  $\epsilon$  is lightest.  $F_0$  particles synthesize all the enzymes required to operate Krebs' cycle.

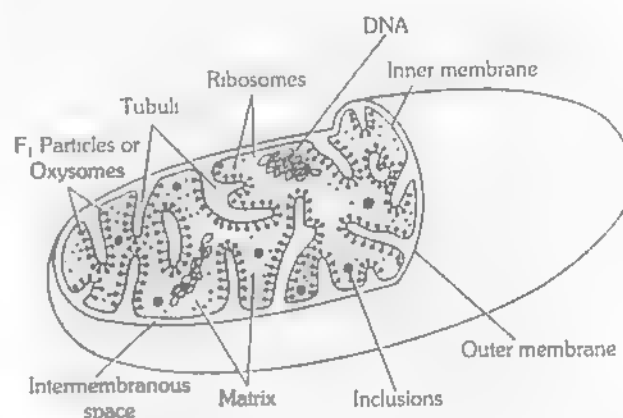


Fig : 3.1-3 Mitochondria of plant cell

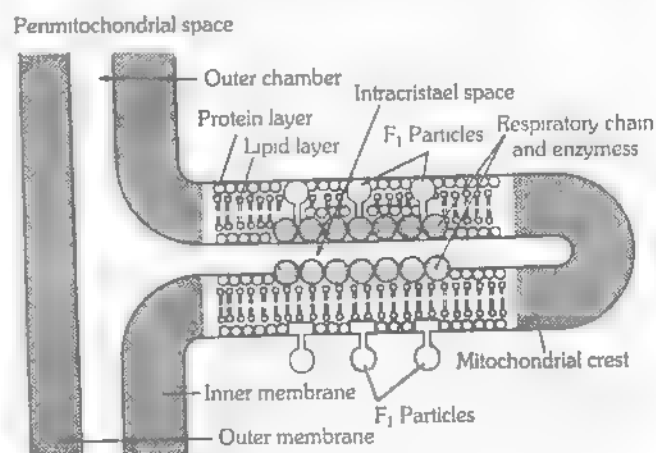


Fig : 3.1-4 Structure of inner membrane of mitochondria



**Semi-autonomous nature of mitochondrion :** Mitochondria contain all requirements of protein synthesis :

- (1) 70 S ribosomes.
- (2) DNA molecules (rich in G-C ratio) to form mRNA and also replicate.
- (3) ATP molecules to provide energy.

The mitochondria can form some of the required proteins but for most of proteins, these are dependent upon nuclear DNA and cytoplasmic ribosomes, so the mitochondria are called semi-autonomous organelles.

According to endosymbiotic origin of mitochondria by Kirms Altman, mitochondria were initially a free living, aerobic bacteria which during to the process of evolution entered an anaerobic cell and become established as mitochondria. This theory is supported by many similarities which exist between bacteria and mitochondria

**Chemical composition :** Cohn gave the chemical composition of mitochondrion :

Proteins = 65 - 70% ; Lipids = 25 - 30% (90% phospholipids and 10% cholesterol, Vit. E., etc.) ; RNA = 5 - 7%. Some amount of DNA 2 - 5%.

The mitochondrial matrix has many catabolic enzymes like cytochrome oxidase and reductases, fatty acid oxidase, transaminase, etc

#### Enzymes of Mitochondria

- (1) **Outer membrane :** Monoamine oxidase, glycerophosphatase, acyltransferase, phospholipase A.
- (2) **Inner membrane :** Cytochrome b, c<sub>1</sub>, c, a, (cyt. b, cyt. c<sub>1</sub>, cyt. c, cyt. a, cyt. a<sub>3</sub>) NADH, dehydrogenase, succinate dehydrogenase, ubiquinone, flavoprotein, ATPase.
- (3) **Perimitochondrial space :** Adenylate kinase, nucleoside diphosphokinase.
- (4) **Inner matrix :** Pyruvate dehydrogenase, citrate synthase, aconitase, isocitrate dehydrogenase, fumarase,  $\alpha$  - Ketoglutarate dehydrogenase, malate dehydrogenase.

**Origin :** Mitochondria are self-duplicating organelles due to presence of DNA molecules so new mitochondria are always formed by growth and division of pre-existing mitochondria by binary fission.

#### Functions

- (1) Mitochondria are called power house or storage batteries or ATP mills formation of ATP is called oxidative phosphorylation.
- (2) Intermediate products of cell respiration are used in the formation of steroids, cytochromes, chlorophyll, etc.
- (3) These are also seat of some amino acid biosynthesis.
- (4) Mitochondria also regulate the calcium ion concentration inside the cell.

(5) Site of thermiogenesis.

(6) Yolk nucleus (a mitochondrial cloud and golgi bodies) controls vitellogenesis.

(7) Mitochondria of spermatid form nebenkern (middle piece) of sperm during spermiogenesis

(8) Mitochondria release energy during respiration.

(9) Mitochondria contain electron transport system.

#### Plastids

Plastids are semiautonomous organelles having DNA, RNA, Ribosomes and double membrane envelope. These are largest cell organelles in plant cell.

#### History

- (1) Haeckel (1865) discovered plastid, but the term was first time used by Schimper (1883).
- (2) A well organised system of grana and stroma in plastid of normal barley plant was reported by de Von Wettstein.
- (3) Park and Biggins (1964) gave the concept of quantasomes.
- (4) The term chlorophyll was given by Pelletier and Caventou, and structural details were given by Willstatter and Stall
- (5) The term thylakoid was given by Menke (1962)
- (6) Fine structure was given by Mayer.
- (7) Ris and Plaut (1962) reported DNA in chloroplast and was called plastidome.

**Types of plastids :** According to Schimper, Plastids are of 3 types: Leucoplasts, Chromoplasts and Chloroplasts.

**Leucoplasts :** They are colourless plastids which generally occur near the nucleus in nongreen cells and possess internal lamellae. Grana and photosynthetic pigments are absent. They mainly store food materials and occur in the cells not exposed to sunlight e.g., seeds, underground stems, roots, tubers, rhizomes etc. These are of three types.

- (1) **Amyloplast :** Synthesize and store starch grains. e.g., potato tubers, wheat and rice grains.
- (2) **Elaoplast (Lipidoplast, Oleoplast) :** They store lipids and oils e.g., castor endosperm, tube rose, etc
- (3) **Aleuroplast (Proteinoplast) :** Store proteins e.g., aleurone cells of maize grains.

**Chromoplasts :** Coloured plastids other than green are known as chromoplasts. These are present in petals and fruits. These also carry on photosynthesis. These may arise from the chloroplasts due to replacement of chlorophyll by other pigments

Green tomatoes and chillies turn red on ripening because of replacement of chlorophyll molecule in chloroplasts by the red pigment lycopene in tomato and capsanthin in chillies. Thus, chloroplasts are changed into chromatoplast

All colours (except green) are produced by flavins, flavenoids and cyanin. Cyanin pigment is of two types one is anthocyanin (blue) and another is erythrocyanin (red). Anthocyanin are water soluble pigments and found in cell sap of vacuole

**Chloroplast** : Discovered by Sachs and named by Schimper. They are greenish plastids which possess photosynthetic pigments. Chloroplast are also known as factory for synthesis of sugars.

**Number** : It is variable. Number of chloroplast is 1 in *Spizopyra indica*, 2 in *Zygnema*, 16 in *S. rectospora*, upto 100 in mesophyll cells. The minimum number of one chloroplast per cell is found in *Ulothrix* and species of *Chlamydomonas*

**Shape** : They have various shapes

Shape	Example
Cup shaped	<i>Chlamydomonas</i> sp
Stellate shaped	<i>Zygnema</i> .
Collar or girdle shaped	<i>Ulothrix</i>
Spiral or ribbon shaped	<i>Spirogyra</i>
Reticulate/net like	<i>Oedogonium</i>
Discoid	<i>Voucheria</i>
Spherical	<i>Chlorella</i>
Biconvex/ovoid	<i>Angiosperm</i>

**Size** : It ranges from 3 – 10  $\mu\text{m}$  (average 5  $\mu\text{m}$ ) in diameter. The discoid chloroplast of higher plants are 4 – 10  $\mu\text{m}$  in length and 2– 4  $\mu\text{m}$  in breadth. Chloroplast of *Spirogyra* may reach a length of 1 mm. Sciophytes (Shade plant) have larger chloroplast

**Chemical composition** : Proteins 50 – 60%; Lipids 25 – 30%; Chlorophyll – 5– 10 %; Carotenoids (carotenes and xanthophylls) 1 –2%; DNA – 0.5%, RNA 2 – 3%; Vitamins K and E; Quinines, Mg, Fe, Co, Mn, P, etc. in traces.

**Ultrastructure** : It is double membrane structure. Both membranes are smooth. The inner membrane is less permeable than outer but rich in proteins especially carrier proteins. Each membrane is 90 – 100 Å thick. The inter-membrane space is called the periplastidial space. Inner to membranes, matrix is present, which is divided into two parts

(1) **Grana** : Inner plastidial membrane of the chloroplast is invaginated to form a series of parallel membranous sheets, called lamellae, which form a number of oval – shaped closed sacs, called thylakoids. Thylakoids are structural and functional elements of chloroplasts

Along the inner side of thylakoid membrane, there are number of small rounded para-crystalline bodies, called quantasomes (a quantasome is the photosynthetic unit)

Park and Biggins (1964) discovered quantasomes. Each quantasome contains about 230 chlorophyll molecules (160 chl 'a' and 70 chl. 'b') and 50 carotenoid molecules.

In eukaryotic plant cells, a number of thylakoids are superimposed like a pile of coins to form a granum. The number of thylakoids in a granum ranges from 10-100 (average number is 20-50). Adjacent grana are interconnected by branched tubules, called stromal lamellae or Fret-channel or Fret membrane's.

(2) **Stroma** : It is transparent, proteinaceous and watery substance. Dark reaction of photosynthesis occurs in this portion. Stroma is almost filled with "Rubisco" (about 15% of total enzyme, protein) enzyme  $\text{CO}_2$  is accepted by this enzyme.  $\text{CO}_2$  assimilation results in carbohydrate formation. It has 20 – 60 copies of naked circular double stranded DNA.

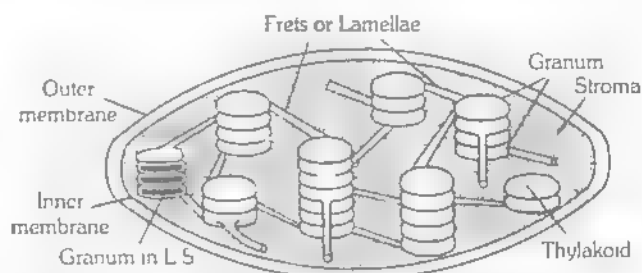


Fig : 3.1-5 A chloroplast in section (diagrammatic)

#### Pigments of chloroplast

**Chlorophyll a** :  $\text{C}_{55}\text{H}_{72}\text{O}_5\text{N}_4\text{Mg}$  (with methyl group)

**Chlorophyll b** :  $\text{C}_{55}\text{H}_{70}\text{O}_6\text{N}_4\text{Mg}$  (with aldehyde group)

**Chlorophyll c** :  $\text{C}_{35}\text{H}_{32}\text{O}_5\text{N}_4\text{Mg}$

**Chlorophyll d** :  $\text{C}_{54}\text{H}_{70}\text{O}_6\text{N}_4\text{Mg}$

**Bacteriochlorophyll** ( $\text{C}_{55}\text{H}_{74}\text{O}_6\text{N}_4\text{Mg}$ ) or chlorobium chlorophyll present in photosynthetic bacteria. These pigments are red in acidic and blue in alkaline medium.

**Carotenoids** : These are hydrocarbons, soluble in organic solvents. These are of two types :

(1) **Carotenes** :  $\text{C}_{40}\text{H}_{56}$  derivatives of vitamin A. Carrot coloured  $\alpha, \beta, \gamma$  carotene, lycopene, etc.  $\beta$  - carotene most common

(2) **Xanthophyll** :  $\text{C}_{40}\text{H}_{56}\text{O}_2$ , yellowish in colour, fucoxanthin, violaxanthin. Molar ratio of carotene and xanthophyll in young leaves is 2 : 1.

**Origin of chloroplast** : Plastids, like the mitochondria, are self duplicating organelles. These develop from colourless precursors, called proplastids. They are believed to be evolved from endosymbiont origination.

#### Functions

(1) It is the site of photosynthesis, (light and dark reaction).

(2) Photolysis of water, reduction of NADP to  $\text{NADPH}_2$  take place in granum

(3) Photophosphorylation through cytochrome  $b_6 f$ , plastocyanine and plastoquinone etc

(4) They store starch or factory of synthesis of sugars

(5) Chloroplast store fat in the form of plastoglobuli

(6) They maintain the percentage of  $\text{CO}_2$  and  $\text{O}_2$  in atmosphere

## Endoplasmic reticulum (ER)

It is well developed electron microscopic network of interconnected cisternae, tubules and vesicles present throughout the cytoplasm, especially in the endoplasm.

**Discovery :** Garner (1897) was first to observe the ergastoplasm in a cell. The ER was first noted by Porter, Claude, and Fullman in 1945 as a network. It was named by Porter in 1953.

**Occurrence :** The ER is present in almost all eukaryotic cells. A few cells such as ova, embryonic cells, and mature RBCs, however, lack ER. It is also absent in prokaryotic cell. In rapidly dividing cells endoplasmic reticulum is poorly developed.

**Ultrastructure :** The ER is made up of three components. All the three structures are bound by a single unit membrane

(1) **Cisternae :** These are flattened, unbranched, sac like structures. They lie in stacks (piles) parallel to one another. They bear ribosomes. They contain glycoproteins named ribophorin-I and ribophorin-II that bind the ribosomes. Found in protein forming cells.

(2) **Vesicles :** These are oval or rounded, vacuole like elements, scattered in cytoplasm. These are also studded with ribosomes.

(3) **Tubules :** Wider, tubular, branched elements mainly present near the cell membrane. They are free from ribosomes. These are more in lipid forming cells.

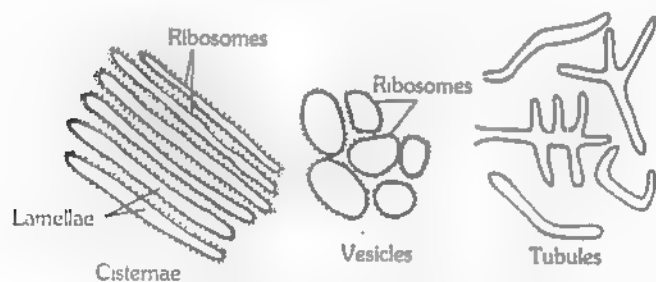


Fig : 3.1-6 Elements of Endoplasmic Reticulum

**Types of ER :** Depending upon the presence of ribosomes, the ER has been categorised into two types :

(1) **A smooth or Agranular endoplasmic reticulum (SER) :** It consists mainly of tubules and vesicles. It has no ribosomes associated to it. It is well developed in the muscle cells, adipose tissue cells, interstitial cells, glycogen storing liver cells, etc. and the cells that synthesize and secrete steroids. SER also takes part in synthesis of vitamins, carbohydrates and detoxification. It gives rise to sphaerosomes. It occurs in cells engaged in producing large quantity of lipids

(2) **Rough or Granular endoplasmic reticulum (RER) :** It mainly consists of cisternae. It has ribosomes attached on its cytoplasmic surface. It is abundant in cells engaged in production and excretion of proteins, e.g., plasma cells, goblets cells, pancreatic acinus cells and certain liver cells. The RER is more stable than SER. The RER is basophilic due to the presence of ribosomes. Ribosomes are attached to ER through hydrophobic interaction.

A third type annulate endoplasmic reticulum was discovered by Mecullo in 1972. It may be smooth or rough having pores like nuclear envelop

**Origin :** RER is formed from nuclear membrane while SER is formed from RER by loss of ribosomes. Rough vesicles originate only from RER after homogenisation of cell. RER breaks in small fragments (Vesicles) and it is called microsome (This is not a cell organelle).

### Functions

- (1) Synthesis and secretion of specific proteins via – golgi bodies.
- (2) Provides surface for synthesis of cholesterol, steroid, ascorbic acid, visual pigments and hormones e.g., testosterone and estrogen.
- (3) It helps in glycogenolysis in the liver cells and brings about detoxification (SER).
- (4) ER is a component of cytoskeleton (Spread as a net) of cell and provides mechanical support and shape to the cell.
- (5) ER acts as segregation apparatus and divides the cytoplasm into chambers. Compartmentalisation is most necessary for cellular life.
- (6) It participates in the formation of cell-plate during cytokinesis in the plant cells by the formation of phragmoplasts.
- (7) ER forms 30–60% part of total membranous system.
- (8) It gives rise to vacuoles

(9) **Sarcoplasmic reticulum :** It is a modified SER striated muscle fibres (Veratti, 1902) which forms a network of interconnected tubules in the sarcoplasm. It helps in conduction of motor nerve impulses throughout the muscle fibre and in the removal of lactic acid so prevents muscle fatigue. It is called "Sarcoplasmic reticulum" in muscle and "Nissl's granules" in nerve cells, myloid body in retinal cells

## Golgi complex

Golgi complex is made up of various membranous system e.g., cisternae, vesicles and vacuoles. These are also called golgi bodies, golgisomes, lipochondrion, dictyosomes, Dalton complex, idiosomes or Baker's body and "traffic police" of the cell.

**Discovery :** First observed by George (1867) but its morphological details were given by Camillo Golgi (1898), in nerve cells of barn owl and cat

**Occurrence :** It is present in all eukaryotic cells. In plants, these are scattered irregularly in the cytoplasm and called as "dictyosomes". These are absent in bacteria and blue green algae, RBCs, spermatozoa of bryophytes and pteridophytes, and sieve tube cells of phloem of angiosperm. The number of Golgi bodies/dictyosomes is generally 9 – 10 in a plant cell but is very high in cells engaged in secretory activity (e.g., root cap cells). The number of golgi body is increased during cell division. Golgi body surrounded by a zone of protoplasm which is devoid of cell organelles called zone of exclusion (Morre, 1977).

**Structure :** Under transmission electron microscope the structure of golgibodies was study by Dalton and Felix (1954), golgi body is made of 4 parts.

(1) **Cisternae** : Golgi apparatus is made up of stack of flat sac like structure called cisternae. The margins of each cisterna are gently curved so that the entire golgi body takes on a cup like appearance. The golgi body has a definite polarity. The cisternae at the convex end of the dictyosome comprises forming face (F. face) or cis face. While the cisternae at the concave end comprises the maturing face (M. face) or trans face. The forming face is located next to either the nucleus or endoplasmic reticulum. The maturing face is usually directed towards the plasma membranes. It is the functional unit of golgi body.

(2) **Tubules** : These arise due to fenestration of cisternae and it forms a complex network.

(3) **Secretory vesicles** : These are small sized components each about 40 Å in diameter present along convex surface of edges of cisternae. These are smooth and coated type of vesicles.

(4) **Golgian vacuoles** : They are expanded part of the cisternae which have become modified to form vacuoles. The vacuoles develop from the concave or maturing face. Golgian vacuoles contain amorphous or granular substance. Some of the golgian vacuoles function as lysosomes

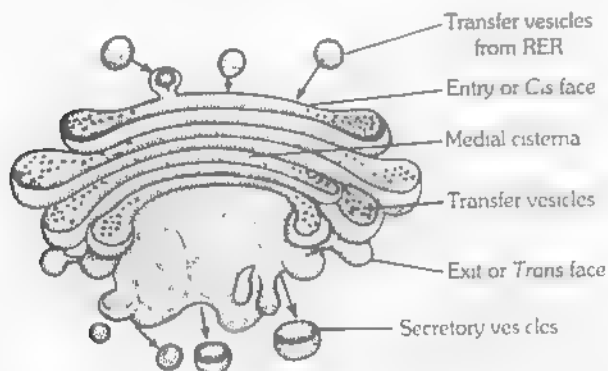


Fig : 3.1-7 Structure of Golgi complex

**Origin** : Most accepted view is that golgi body originates from RER-that has lost its ribosomes from this RER arise transport vesicles that contain Golgi membrane and fuse with the saccule on the forming face of Golgi apparatus. This is why this face is called the forming face.

#### Functions

(1) The main function of golgi body is secretion, so it is large sized among the secretory cells.

(2) Glycosidation of lipids i.e., addition of oligosaccharides to produce glycolipids.

(3) Glycosylation of proteins i.e., addition of carbohydrate to produce glycoproteins.

(4) Formation of primary lysosomes.

(5) Golgi body forms the cell plate. During cell division by secreting hemicellulose formation of enzyme and hormones (Thyroxine) etc.

(6) In oocytes of animal, golgi apparatus functions as the centre around which yolk is deposited i.e., vitellogenesis.

(7) Membrane of the vesicles produced by golgi apparatus join in the region of cytokinesis to produce new plasmalemma.

(8) It is also called export house of cell.

(9) Golgi body contains phospholipids, proteins, enzymes and vitamin

(10) The golgi complex gives rise to the acrosome in an animal sperm.

## Lysosomes

Lysosomes are electron microscopic, vesicular structures of the cytoplasm, bounded by a single membrane (lipoproteinous) which are involved in intracellular digestive activities, contains hydrolytic enzymes, so called lysosomes.

### Discovery

(i) These were first discovered by a Belgian biochemist, Christian de Duve (1955) in the liver cells and were earlier named pericanalicular dense bodies.

(ii) Term Lysosome was given by Novikoff under the study of electron microscope

(iii) Matile (1964) was first to demonstrate their presence in plants, particularly in the fungus *Neurospora*. Polymorphism in lysosomes were described by De Robertis et. al (1971).

**Occurrence** : These are absent from the prokaryotes but are present in all eukaryotic animal cells except mammalian RBCs. They have been recorded in fungi, *Euglena*, cotton and pea seeds.

**Shape** : These are generally spherical in shape but are irregular in plant root tip cells.

**Size** : Size range is 0.2-0.8  $\mu\text{m}$  while size is 0.5  $\mu\text{m}$  (500 nm).

**Types of Lysosomes** : On the basis of their contents, four types of lysosomes are recognised.

(1) **Primary Lysosomes** : A newly formed lysosome contains enzymes only. It is called the primary lysosomes. Its enzymes are probably in an inactive state.

(2) **Secondary Lysosomes** : When some material to be digested enters a primary lysosome, the latter is named the secondary lysosome, or phagolysosome or digestive vacuole, or heterophagosome.

(3) **Tertiary lysosomes/Residual bodies** : A secondary lysosome containing indigestible matter is known as the residual bodies or tertiary lysosome. The latter meets the cell by exocytosis (epagy)

(4) **Autophagosomes/Autolysosomes** : A cell may digest its own organelles, such as mitochondria, ER. This process is called autophagy. These are formed of primary lysosomes. The acid hydrolases of lysosomes digest the organelles thus, it is called autophagosome. The lysosome are sometimes called disposal units/suicidal bags. Sometime they get burst and causes the destruction of cell or tissue

**Chemical composition** : Matrix of primary lysosome is formed of hydrolases, which is involved in hydrolysis or polymeric compounds, that operate in acidic medium at pH 5, so called acid hydrolases. Upto now 50 types of enzyme have been reported These are as .

Proteases (cathepsin and collagenase), Nucleases (DNAse and RNAse), Glycosidases ( $\beta$ -galactosidase,  $\beta$ -glucuronidase), Phosphatases (ATPase, acid phosphatase /marker enzyme).

### Functions

- (1) Lysosomes of sperms provide enzyme for breaking limiting membrane of egg e.g., hyaluronidase enzyme.
- (2) Lysosomes functions as trigger of cell division or initiate cell division by digesting repressor molecules.
- (3) Nucleases (DNase) of lysosomes may cause gene mutations which may cause disease like leukemia or blood cancer (partial deletion of 21<sup>st</sup> chromosome).
- (4) Sometimes residual bodies accumulate inside the cells leading to storage diseases e.g., a glycogen storage disease called Pompe's disease, polynephritis Hurler's disease (deformed bones due to accumulation of mucopolysaccharides).
- (5) Lysosomes also engulf the carcinogens.

### Ribosome

The ribosomes are smallest known electron microscopic without membrane, ribonucleo-protein particles attached either on RER or floating freely in the cytoplasm and are the sites of protein synthesis.

**Discovery :** In 1943 *Claude* observed some basophilic bodies and named them as microsome. *Palade* (1955) coined the term ribosome (from animal cell). Ribosomes in nucleoplasm were observed by *Tsao* and *Sato* (1959). First isolated by *Tissieres* and *Watson* (1958) from *E. coli*. Ribosomes found in groups are termed as polyribosomes or ergosomes (*Rich* and *Warner* 1963 observed first time polyribosomes).

**Occurrence :** In prokaryotes ribosomes are found only in free form in the cytoplasm. While in the eukaryotes the ribosomes are found in two forms in the cytoplasm, free form and bind form (bound on RER and outer nuclear membrane). These are also reported inside some cell organelles like mitochondria and plastids respectively called mitoribosomes and plastidoribosomes.

#### Types of ribosomes

- (1) **70S ribosomes :** Found in prokaryotes, mitochondria and plastid of eukaryotes.
- (2) **80S ribosomes :** Found in cytoplasm of eukaryotes
- (3) **77S, 60S and 55S ribosomes :** *Levine* and *Goodenough* (1874) observed 77S ribosomes in fungal mitochondria 60S ribosomes in animal mitochondria and 55S in mammalian mitochondria.

**Structure :** Each ribosome is formed of two unequal subunits, which join only at the time of protein synthesis. In 70S and 80S ribosomes, 50S and 30S, 60S and 40S are larger and smaller subunits respectively. Larger subunits is dome shaped and attached to ER by glycoproteins called "ribophorins".

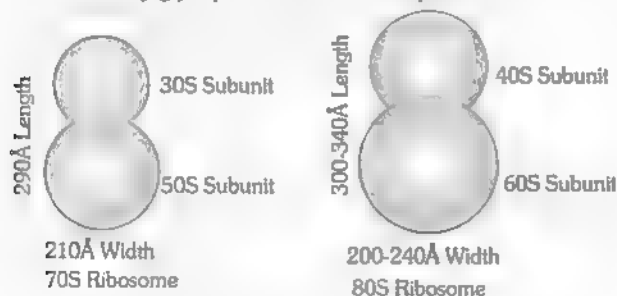


Fig : 3.1-8 Structure of 70S and 80S ribosome

Smaller subunit is oval shaped and fits as a cap on flat side of larger subunit. Ribosomes are attached to ER through hydrophobic interactions.

**Chemical composition :** Ribosomes are chemically composed of rRNA and proteins Ribonucleo-Protein (RNP). 70S ribosomes has 60-65% rRNA and 35-40% proteins (ratio is 2:1). rRNAs are of three types : 23S type and 5S type rRNAs in 50S and 16S type rRNA in 30S sub-units.

80S ribosome has 45% rRNA and 55% proteins (ratio is about 1 : 1). r-RNA are of four types : 28S, 5S and 5.8S types of rRNAs in 60S and 18S type rRNA in 40S sub-units.

A  $1 \times 10^{-3}$  (0.001 M) molar concentration of  $Mg^{++}$  is needed for the structural cohesion of ribosomes i.e., for holding the two subunits together. If this concentration is increased by ten folds, two ribosomes unite to form a dimer. By decreasing the  $Mg^{++}$  conc. to normal, the dimer breaks into monomers (single ribosomes).

#### Biogenesis of ribosome

- (1) In eukaryotes the ribosomal RNAs like 18S, 5.8S and 28S are synthesized by nucleolus and 5S RNA out of the nucleus.
- (2) In prokaryotes both rRNA and its protein are synthesized as well as assembled by cytoplasm.

**Polyribosomes or Polysomes :** When many ribosomes (generally 6 – 8) are attached at some mRNA strand. It is called polysome. The distance between adjacent ribosomes is of 90 nucleotides. These are functional unit of protein synthesis.

#### Functions

- (1) Ribosomes are also called protein factories of the cell or work branch of proteins.
- (2) Free ribosomes synthesize structural proteins and bounded ribosomes synthesize proteins for transport.
- (3) Ribosomes are essential for protein synthesis.
- (4) Help in the process of photosynthesis.
- (5) Enzyme peptidyl transferase occurs in large subunit of ribosome which helps in protein synthesis.
- (6) Newly formed polypeptide is protected from degradation by cytoplasmic enzymes in large sub-unit of ribosomes before releasing it into RER lumen.

### Microbodies

#### (1) Sphaerosomes

**Discovery :** These were first observed by *Hanstein* (1880) but discovered by *Perner* (1953). Term sphaerosomes was given by *Dangeard*.

**Occurrence :** Sphaerosomes, arise from the E.R. These are found in all the plant cells which involves in the synthesis and storage of lipids i.e., endosperm and cotyledon of oil seeds.

**Shape, size and structure :** These are spherical or oval in shape about 0.5-2.5  $\mu m$  in diameter. They contain hydrolytic enzymes like protease, ribonuclease, phosphatase, esterase etc. They are bounded by a single unit membrane

**Function :** The main function of sphaerosomes is to help in lipid metabolism. These are also known as plant lysosomes.

**(2) Peroxisomes (Uricosomes)**

**Discovery :** These were discovered by Tolbert (1969). De Duve (1965) isolated certain sac like organelles from various types of animals and plants. These were called peroxisomes because these contain peroxide producing enzymes (oxidases) and peroxide destroying enzymes (catalases).

**Occurrence :** These are found in photosynthetic cells of plants. In animals peroxisomes are found in vertebrates (cells of liver, kidney), brain, small intestine, testis and adrenal cortex), invertebrates and protozoans e.g., *Paramecium*.

**Shape, size and structure :** These are spherical in shape, about  $1.5\ \mu\text{m}$  in size. They are bounded by a single unit membrane

Their membrane is permeable to amino acids, uric acids, etc. They contain four enzymes of  $\text{H}_2\text{O}_2$  metabolism. The enzymes urate oxidase, d-amino oxidase,  $\alpha$ -hydroxy acid oxidase produce  $\text{H}_2\text{O}_2$  whereas the catalases plays a significant protective role by degrading  $\text{H}_2\text{O}_2$  because  $\text{H}_2\text{O}_2$  is toxic for cells.

**Function :** These are involved in the formation and degrading of  $\text{H}_2\text{O}_2$ . Plant peroxisomes are also involved in photorespiration.

**(3) Glyoxysomes**

**Discovery :** These were discovered by Beevers in 1961 and Briedenbach in 1967.

**Occurrence :** These are found in fungi, some protists and germinating fatty seeds where insoluble lipid food reserves must be turned into soluble sugars. Absent in animal cell

**Shape, size and structure :** These are spherical in shape, about  $0.5\text{--}1\ \mu\text{m}$  in size, they contain enzymes of metabolism of glycolic acid via glyoxylate cycle and bounded by a unit membrane. These also contain enzymes for  $\beta$ -oxidation of fatty acids. Produced acetyl CoA. The latter is metabolised in glyoxylate cycle to produce carbohydrates.

**Functions :** The main function of glyoxysomes is conversion of fats into carbohydrates.

**(4) Lomasomes :** These are sac like structures found between cell wall and plasmalemma in the haustoria of fungal hyphae. These were discovered by Moore and McAlear (1961). Webster called them border bodies

**Centrosome**

**Discovery :** Centrosome was first discovered by Van Benden (1887). Term and structure was given by T. Boweri

**Occurrence :** It is found in all the animal cell except mature mammalian RBC's. It is also found in most of protists and motile plant cells like antherozoids of ferns, zoospores of algae and motile algal forms e.g., *Chlamydomonas* but is absent in prokaryotes, fungi, gymnosperms and angiosperms

**Structure :** Centrosome is without unit membrane structure. It is formed of two darkly stained granules called centrioles, which are collectively called diplosome. These centrioles are surrounded by a transparent cytoplasmic area called centrosphere or Kinetoplasm. Centriole and centrosphere are collectively called centrosome. Each centriole is a microtubular structure and is formed of microtubules arranged in 9+0 manner (all the 9 microtubules are peripheral in position). Inside the microtubules, there is an intra-centriolar or cart-wheel structure which is formed of a central hub (about  $25\text{\AA}$  in diameter) and 9 radial spokes or radial fibres

**Chemical composition :** Centrosome is lipoproteinaceous structure. The microtubules of centriole are composed of protein tubulin and some lipids. They are rich in ATPase enzyme.

**Origin :** The daughter centriole is formed from the pre-existing centriole in  $G_2$  of interphase so called self-replicating organelle

**Functions**

(1) The centrioles help organising the spindle fibres and astral rays during cell division

(2) They provide basal bodies which give rise to cilia and flagella

**Cilia and Flagella**

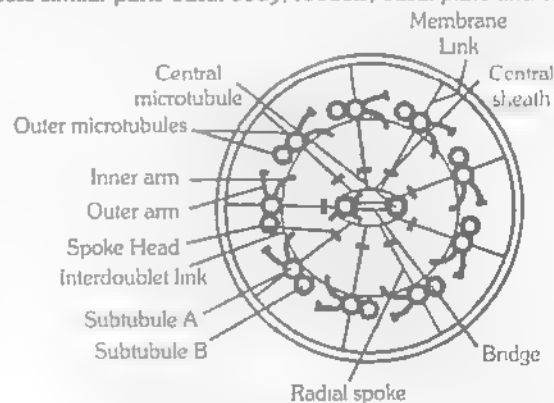
**Discovery :** Flagellum presence was first reported by Englemann (1868). Jansen (1887) was first scientist to report the structure of sperm flagellum

**Definition :** Cilia and flagella are microscopic, hair or thread-like motile structures present extra-cellularly but originate intra-cellularly from the basal body

**Occurrence :** Cilia are found in all the ciliate protozoans e.g., *Paramecium*, *Vorticella* etc

Flagella are found in all the flagellate protozoans e.g., *Euglena*, *Trichonympha* etc

**Structure :** Both cilia and flagella are structurally similar and possess similar parts-basal body, rootlets, basal plate and shaft



**Fig : 3.1-9 T.S. Cilium or Flagellum**

(1) **Basal body :** These are also termed as blepharoplast (kinetosome) or basal granule. It is present below the plasma membrane in cytoplasm. The structure is similar to centriole made of 9 triplets of microtubules

(2) **Rootlets :** Made of microfilament and providing support to the basal body

(3) **Basal plate** : Central fibril develop in this area. It is highly dense and lie above plasma-membrane. The basal body and the shaft at the level of plasma membrane

(4) **Shaft** : It is the hair like projecting part of cilia and flagella which remains outside the cytoplasm. It has 9 doublet of microtubules in radial symmetry. These are called axonema. Each axonema has 11 fibrils, 9 in the periphery and 2 in the centre. The arrangement is called 9 + 2 pattern

**Chemical composition** : Chemically, the central tubules are formed of dynein protein while the peripheral microtubules are formed of tubulin protein

**Type of flagella** : There are two types of flagella.

(1) **Tinsel type** : In this, flagellum has lateral hair-like processes, called flimmers or mastigonemes

(2) **Whiplash type** : In this, flagellum has no flimmers

#### Functions

(1) They help in locomotion, respiration, cleaning, circulation, feeding, etc

(2) Being protoplasmic structure they can function as sensory organs.

(3) They show sensitivity to changes in light, temperature and contact

**Table : 3.1-5 Difference between cilia and flagella**

Cilia	Flagella
More in number (may be upto 14,000 per cell)	Less in number (1-8)
Small sized (5-10 $\mu\text{m}$ )	Large sized (upto 100-200 $\mu\text{m}$ )
Generally distributed on whole body.	Generally located at anterior end of body
Beat in either metachronous or synchronous coordination	Beat independently
Sweeping or rowing motion.	Undulatory motion.
Locomotion, feeding, circulation, etc	Only locomotion.

#### Cytoskeleton

In eukaryotic cell, a framework of fibrous protein elements became necessary to support the extensive system of membranes. These elements collectively form cytoskeleton of the cell. There are of three types

(1) **Microtubules** : These were first discovered by De Robertis and Franchi (1953) in the axons of medullated nerve fibres and were named neurotubules. The term was coined by Slautterback (1963).

**Position** : The microtubules are electron-microscopic structures found only in the eukaryotic cellular structures like cilia, flagella, centriole, basal-body, astral fibres, spindle fibres

**Structure** : A microtubule is a hollow cylindrical structure of about 250 Å in diameter with about 150 Å lumen. Its wall is about 50 Å thick. Its wall is formed of 13 parallel, proto-tubules.

**Chemical composition** : These are mainly formed of tubulin protein. A tubulin protein is formed of 2 sub-units :  $\alpha$ -tubulin molecule and  $\beta$ -tubulin molecule which are alternatively in a helical manner

#### Functions

(1) These form a part of cytoskeleton and help in cell-shape and mechanical support.

(2) The microtubules of cilia and flagella help in locomotion and feeding.

(3) The microtubules of asters and spindle fibres of the mitotic apparatus help in the movement of chromosomes towards the opposite poles in cell-division.

#### (2) Microfilament

**Discovery** : These were discovered by Paleviz et. al. (1974)

**Position** : These are electron-microscopic, long, narrow, cylindrical, non-contraction and proteins structures found only in the eukaryotic cytoplasm. These are present in the microvilli, muscle fibres (called myofilaments) etc. But these are absent in prokaryotes.

**Structure** : Each microfilament is a solid filament of 50-60 Å diameter and is formed of a helical series of globular protein molecules. These are generally grouped to form bundles.

**Chemical composition** : These are mainly formed of actin-protein (contractile).

#### Functions

(1) The microfilaments forms a part of cytoskeleton and change the cell shape during development, motility and division.

(2) The microfilaments bring about directed movements of particles and organelles along them in the cell

(3) The microfilaments also produce streaming movements of cytoplasm.

(4) The microfilaments are responsible for the movement of cell membrane during endocytosis and exocytosis.

#### (3) Intermediate filaments

**Location** : They are supportive elements in the cytoplasm of the eukaryotic cells. They are missing in mammalian RBCs.

**Structure** : The IFs are somewhat larger than the microfilaments and are about 10 nm thick. They are solid, unbranched and composed of nonmotile structural proteins, such as keratin, desmine, vimentin.

#### Functions

(1) They form a part of cytoskeleton that supports the fluid cytosol and maintains the shape of the cell

(2) They provided strength to the axons

(3) They keep nucleus and other organelles in place.

#### Nucleus

The nucleus also called director of the cell. It is the most important part of the cell which directs and controls all the cellular function



**Discovery :** The nucleus was first observed by *Robert Brown* (1831), in orchid root cells. Nucleus plays determinative (in heredity) role in cell and organism, that was experimentally demonstrated by *Hammerling* (1934) in surgical experiments with green marine unicelled algae *Acetabularia*

**Occurrence :** A true nucleus with definite nuclear membrane and linear chromosome, is present in all the eukaryotes except mature mammalian RBCs, sieve tube cell of phloem, tracheids and vessels of xylem. The prokaryotes have an incipient nucleus, called nucleoid or prokaryon or genophore or false nucleus.

**Number :** Usually there is a single nucleus per cell i.e., mononucleate condition, e.g., *Acetabularia*.

(1) **Anucleate (without nucleus) :** RBCs of mammals, phloem sieve tube, tracheids and vessels of xylem.

(2) **Binucleate :** e.g., Ciliate, Protozoans like *Paramecium*.

(3) **Polynucleate :** e.g., fungal hyphae of *Rhizopus*, *Vaucheria*. Polynucleate condition may be because of fusion of a number of cells. i.e., syncytium, coconut endosperm or by free nuclear divisions without cytokinesis i.e., coenocyte.

**Shape :** It varies widely, generally spherical e.g., cuboidal germ cells, oval e.g., columnar cells of intestine, bean shaped in *paramecium*, horse-shoe shaped in *Vorticella*, bilobed, e.g., WBCs (acidophils), 3 lobed e.g., basophil, multilobed e.g., neutrophils, long and beaded form (moniliform) e.g., stentor and branched in silk spinning cells of platy phalyx insect larva.

**Size :** The size of nucleus is variable i.e., 5 – 30 $\mu$ . In metabolically active cells size of the nucleus is larger than metabolically inactive cells

#### Chemical composition

Proteins = 80%, DNA = 12%, RNA = 5%, Lipids = 3%

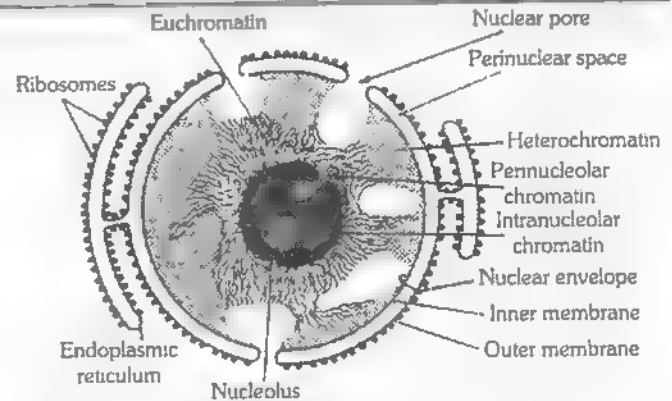
Enzymes like polymerases are abundantly present and help in synthesis of DNA and RNA.

**Ultrastructure :** The nucleus is composed of following structure.

(1) **Nuclear membrane :** It is also called nuclear envelope or nucleolemma or karyotheca, was first discovered by *Ercleb* (1845).

**Structure :** It is a bilayered envelope. Each membrane is about 60-90Å thick lipoproteinous and trilaminar. Outer membrane, called ectokaryotheca (with ribosome) and inner membrane is called endokaryotheca (without ribosome). Two membranes are separated by a fluid-filled intermembranous perinuclear space (about 100-300Å).

Nuclear membrane is porous and has 1,000-10,000 octagonal nuclear pores. Each nuclear pore is about 400-1,000 Å in diameter (average size is 800 Å). *Callan* and *Tamlin* (1950) first to observe nuclear pore in nuclear membrane. The nuclear pores are enclosed by circular structure are called annuli. The pore and annuli together are called pore complex or pore basket.



**Fig : 3.1-10 Electron microscopic structure of nucleus**

**Origin :** It is formed by the fusion of ER elements during the telophase of cell division.

#### Functions

(i) It regulates the nucleo-cytoplasmic interactions.

(ii) It allows the passage of inorganic ions, small organic molecules, ribosomal subunits, RNAs and proteins through nuclear pores.

(iii) It maintains the shape of the nucleus.

(2) **The nucleolus (Little nucleus plasmosome) :** It was first observed by *Fontana* (1781) in the skin cells of an eel. *Bowman* (1840) coined term 'nucleolus'. *Wagner* (1840) gave its light microscopic structure.

**Position :** It is generally associated with nucleolar organizer region (NOR) of the nucleolar chromosomes. It is absent in muscle fibres, RBC, yeast, sperm and prokaryotes.

**Number :** Generally, a diploid cell is with two nucleoli but there are five nucleoli in somatic cell of man and about 1000 nucleoli in the oocytes of *Xenopus*.

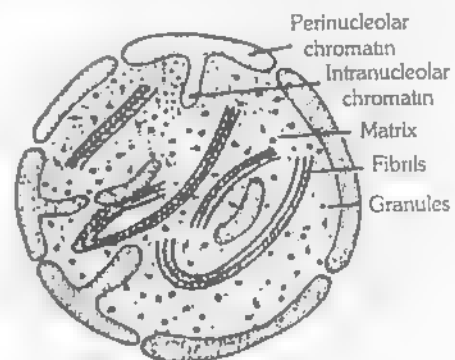
**Structure :** (*De Robertis et al* 1971). A nucleolus is distinguishable into following regions :-

(1) **Chromatin :** The nucleolus is surrounded by perinucleolar chromatin.

(2) **Pars fibrosa :** Fibrils of 80 – 100 Å size form a part of the nucleolus

(3) **Pars granulosa :** Granules of 150 – 200 Å diameter constitute the granular part of the nucleolus. Ribosome formation takes place in this part so it is called assembly line of ribosome.

(4) **Pars amorpha :** The granules and the fibrils lie dispersed in an amorphous proteinaceous matrix. Nucleolus is stained by "pyronine". It is not bounded by any limiting membrane.



**Fig : 3.1-11 Ultrastructure of a Nucleolus**



**Chemical composition :** Nucleolus is mainly formed of RNA and non histone acidic proteins. It is a store house of rRNA.

**Origin :** A nucleolus is formed at specific sites, called the nucleolar organizers, present on certain chromosomes region (NOR)

#### Functions

(i) It is seat of biogenesis of rRNA and also stores rRNA.  
(ii) It plays important role in spindle formation during cell division

(iii) It receives the ribosomal proteins from the cytoplasm, combines the rRNAs and ribosomal proteins to form ribosomal subunits. So it is also called ribosome producing machine or factory

(3) **Nucleoplasm :** It is also called karyolymph. It is transparent, homogenous, semifluid, colloidal, ground substance present inside the nuclear membrane. It contains Nucleic acid (DNA and RNA), Proteins (Basic proteins and acidic protein), Enzyme (DNA and RNA polymerase, NAD synthetase etc ), Minerals (K, Na, Ca, Mg etc.) and Ribonucleoproteins

The nucleoplasm helps in maintaining the shape of nucleus formation of spindle protein of NAD, ATP, DNA, RNAs and ribosomal subunits. Plasmosome and karyosome combinedly called "amphinucleoli".

(4) **Chromatin fibres /Nuclear chromatin :** The nucleoplasm contains many thread like, coiled and much elongated structures which take readily the basic stains such as "basic fuchsin". These thread like structures are known as chromatin fibre. They are uniformly distributed in the nucleoplasm. They are observed only in the "interphase stage".

(5) **Nuclear matrix :** It is network of proteinaceous fibrils. It is outer thicker part is called fibrous lamina (Harris and James, 1952)

#### Chromosome (Gr. chroma = colour soma = body)

Chromosomes were discovered by Hofmeister (1848) in filament of pollen mother cells of *Tradescantia* (Rhoeodiscolour) studied by Strasburger (1875) and given the present name by Waldeyer (1888).

During interphase, chromatin threads are present in the form of a network called chromatin reticulum. At the time of cell division, these thread like structures of chromatin become visible as independent structures, called chromosomes. The haploid set of chromosomes is defined as genome

**Structure :** Each chromosome consists of two coiled filaments throughout its length called chromonemata by Vejdovsky. These have bead like structures called chromomeres which bear genes. Chromatid is a half chromosome or daughter chromosome. The two chromatids are connected at the centromere or primary constriction. Primary constriction (centromere) and secondary constriction gives rise to satellite. The secondary constriction consists of genes which code for ribosomal RNA and nucleolus hence it is called as "nucleolar organizer region". Chromosomes having satellite are called SAT chromosomes. The ends of chromosomes are called "telomeres" (which do not unite with any other structure).

In 1928 Emile Heitz developed a technique for staining of chromosomes. Staining property of chromosomes is called as heteropycnosis. Chromosomes can be stained with basic dye like Janus green. There are two types of regions –

(1) **Heterochromatin :** It is formed of thick regions which are more darkly stained than other areas. It is with condensed RNA which is transcriptionally inactive and late replicating. It generally lies near the nuclear lamina. It is of two type :

(i) **Constitutive heterochromatin :** Occurs in all cells in all stages. e.g., Centromere

(ii) **Facultative heterochromatin :** Formed by inactivation of some gene in some cell in some stages. e.g., Barr body.

(2) **Euchromatin :** It is true chromatin and is formed of thin, less darkly stained areas. It is with loose DNA which is transcriptionally active and early replicating.

**Chemical Composition :** DNA - 40%. Histone - 50%. Other (acid) Proteins - 8.5%. RNA - 1.5%. Traces of lipids, Ca, Mg and Fe. Histone are low molecular weight basic proteins which occur along with DNA in 1 : 1 ratio. Nonhistone chromosomal or NHC proteins are of three types – structural, enzymatic and regulatory. Structural NHC proteins form the core or axis of the chromosome. They are also called scaffold proteins.

#### Metabolically inactive cell inclusions

Within the cytoplasm of a cell there occur many different kinds of non-living structures which are called inclusions or ergastic / Deutoplasmic substances.

(1) **Vacuoles :** The vacuole in plants was discovered by Spallanzani. It is a non-living reservoir, bounded by a differentially or selectively permeable membrane, the tonoplast. The vacuole is filled with cell sap or tonoplasm. This cell sap is generally neutral but at maturity it becomes acidic. They contain water, minerals and anthocyanin pigments. These pigments are responsible for the different colours of flowers.

Some protozoans have contractile vacuoles which enlarge by accumulation of fluid or collapse by expelling them from the cell. The vacuoles may be sap vacuoles, contractile vacuoles or gas vacuoles (pseudo vacuoles)

**Function of vacuoles :** Vacuole maintains osmotic relation of cell which is helpful in absorption of water. Turgidity and flaccid stages of a cell are due to the concentrations of sap in the vacuole.

#### (2) Reserve food material

The reserve food material may be classified as follows :

(i) **Carbohydrates :** Non-nitrogenous, soluble or non-soluble important reserve food material. Starch, cellulose and glycogen are all insoluble.

(a) **Starch :** Found in plants in the form of minute solid grains. Starch grains are of two types :

**Assimilation starch :** It is formed as a result of photosynthesis of chloroplasts

**Reserve starch :** Thick layers are deposited around an organic centre called hilum.

(b) **Glycogen** : Glycogen or animal starch occurs only in colourless plants like fungi

(c) **Inulin** : It is a complex type of polysaccharide, soluble and found dissolved in cell sap of roots of Dahlia, Jerusalem, Artichoke, Dandelion and members of compositae

(d) **Sugars** : A number of sugars are found in solution of cell sap. These include glucose, fructose, sucrose, etc.

(e) **Cellulose** : Chemical formula is  $(C_6H_{10}O_5)_n$ . The cell wall is made up of cellulose. It is insoluble in water

(ii) **Fats and Oils** : These are important reserve food material. These are always decomposed into glycerol and fatty acids by enzymatic action. Fat is usually abundant in cotyledons than in the endosperm. e.g., flax seed produce linseed oil, castor produce castor oil, cotton seeds produce cottonseed oil, etc.

(iii) **Proteins and Amides (Aleurone grains)** : Storage organ usually contain protein in the form of crystalline bodies known as crystalloids (potato). Proteins may be in the form of aleurone grains as in pea, maize, castor, wheat, etc.

(3) **Excretory Products** : The organic waste products of plants are by-product of metabolism. They are classified as :

(i) **Resins** : They are believed to be aromatic compounds consisting of carbon, hydrogen and oxygen and are acidic in nature. Sometimes they are found in combination with gums and are called gum resin. e.g., *Asafoetida* (heeng)

(ii) **Tannins** : They are complex nitrogenous compounds of acid nature having an astringent taste. Presence of tannin in plants makes its wood hard durable and germ proof

(iii) **Alkaloids** : These are organic, basic, nitrogenous substance. They occur in combination with organic acids and most of them are poisonous. From plants, cocaine, hyoscyne, morphine, nicotine, quinine, atropine, strychnine and daturine etc. are extracted

(iv) **Glucosides** : Some glucosides or glycosides function as storage substance e.g., amygdaline of the bitter almond.

(v) **Etherial and Essential oils** : These consist mixture of various hydrocarbons known as terpenes and their oxygen derivatives. They are responsible for flavour of many fruits and scent of many flowers etc. They are volatile and are soluble in water, ether, petroleum etc. e.g., lavender, mint, clove oil, eucalyptus oil, theme oil etc.

(vi) **Mineral matter** : Many minerals are waste products in plants

(a) **Calcium oxalate** : It occurs in the form of crystals of various shapes

**Raphides** : Needle shaped crystals are known as raphides. e.g., In plants like jamikand, *Asparagus*, *Colocasia*, water hyacinth (Jal kumbhi) etc

**Rosette or Sphaeraphides** : Star shaped crystals. They occur in special mucilaginous parenchyma cells of the petiole of arum, water hyacinth, etc. Crystals in the form of cubes are found in tunic of onion bulb. In the leaf of belladonna, these crystals are in the form of sand and also called as sand crystals

**Calcium oxalate crystals** : In members of family solanaceae. They are found as cubics, rods and prisms

(b) **Calcium carbonate** : It is deposited in the form of crystalline masses hanging from a cellulose stalk in enlarged epidermal cells of leaves of *Ficus elastica* (Indian rubber plant) and is called as cystolith.

(vii) **Latex** : It is an emulsion in water having many substances either in suspension or in true solution. It may contain sugars, alkaloids and oils. It is watery in banana, milky white in *Euphorbia*, yellow or orange red in opium (poppy) is dried latex.

(viii) **Organic acids** : Tartaric acid in tamarind, and grapes, citric acid in lemon, orange etc. malic acid in apple and *Bryophyllum*. Oxalic acid in the form of crystals.

(ix) **Gums** : It is formed by decomposition of cellulose cell wall. Gum arabic of commerce is obtained from *Acacia senegal*

## Tips & Tricks

✎ HPLC stands for high performance liquid chromatography

✎ Three dimensional image are obtained with the help of scanning electron microscope and X-ray microscope. Where as all other microscopes give two dimensional image

✎ Tracer isotopes / radioactive isotopes : Which functions like normal elements but emit radiations. They can, therefore, be located by Geiger muller counter or scintillation counter and autoradiography, e.g.,  $^3H$ ,  $^{14}C$ ,  $^{32}P$ ,  $^{35}S$ , etc.

✎ The smallest cell considered so far is of PPLO (Pleuropneumonia like organisms) or *Mycoplasma gallisepticum* i.e.,  $0.1\mu$

✎ Negative charge of the membrane is due to N - acetyl neuraminic acid (NANA)/sialic acid.

✎ Transosomes found in follicular cells of ovary of birds and have triple unit membrane. First reported by Press (1964)

✎ Nehar and Sakmann discovered ion-channels in plasma membrane and they were awarded Noble prize for it in 1971

✎ Singer and Nicolson's model differs from Robertson's model in the arrangement of proteins.

✎ Petite character in yeast and cytoplasmic male sterility in maize are examples of mitochondrial inheritance.

✎ Lehninger discovered oxysomes.

✎ In prokaryotic cell, plasma membrane infolding makes a structure mesosome. Which is analogous structure of mitochondria of eukaryotic cell (both part in respiration)

✎ Chromatophore term was given by Schmitz

✎ Autonomic genome system is present in Mitochondria and chloroplast.

✎ In confocal microscope, the specimen is illuminated by laser beam.



## Ordinary Thinking

## Objective Questions

## Tools and Technique

- Differentiation capacity of compound microscope is [RPMT 1999]
  - 0.275  $\mu\text{m}$
  - 2.75  $\mu\text{m}$
  - 27.5  $\mu\text{m}$
  - None
- A mixture containing DNA fragments a, b, c and d with molecular weights of  $a+b=c$ ,  $a>b$  and  $d>c$ , was subjected to agarose gel electrophoresis. The positions of these fragments from cathode to anode sides of the gel would be [DUMET 2010]
  - b, a, c, d
  - a, b, c, d
  - c, b, a, d
  - b, a, d, c
- A student wishes to study the cell structure under a light microscope having 10X eyepiece and 45X objective. He should illuminate the object by which one of the following colours of light so as to get the best possible resolution [CBSE PMT 2005; WB JEE 2008]
  - Blue
  - Green
  - Yellow
  - Red
- Electron microscope is used for [Kerala CET 2003]
  - Viewing structure of the cell
  - Whole mount study
  - Cell division study
  - Structure of the pollen grain
- A magnification of upto 100 million times is possible in [CBSE PMT 2000; KCET 2001]
  - Scanning electron microscope
  - Electron transmission microscope
  - Scanning probe microscope
  - Photon tunneling microscope
- Resolving power of light microscope is [DPMT 2003]
  - 0.2  $\mu\text{m}$
  - 0.1  $\mu\text{m}$
  - 2  $\mu\text{m}$
  - 100  $\mu\text{m}$
- Electron microscope has revealed the presence of or Which among the following can be seen only under electron microscope [AFMC 1996; MP PMT 1998]
  - Ribosome
  - Chromosome
  - Chloroplast
  - Leucoplast
- Who invented the "electron microscope" [AFMC 2001; BVP 2002; AIIMS 2003; HPMT 2005; MP PMT 2007]
  - Knoll and Ruska
  - Robert Brown
  - Correns
  - Janssen and Janssen
- Which of the following statements is/are true
  - The resolution power of unaided human eye is 100 micrometre
  - The highest resolution is obtained with the light of shortest wavelength
  - Dark field microscope is most useful for viewing the living cells
  - Chromatography is the method of separation of molecular components of the cells present in cytosol
  - In gel filtration chromatography, molecules can be separated in picogram to nanogram quantities
 [Kerala PMT 2008]
  - A, C and D only
  - B and D only
  - C and E only
  - C, D and E only
  - A, B and D only
- 1 nm is equal to [CPMT 1999; JIPMER 2001]
  - 10 Å
  - $10^{-3}$  mm
  - $10^{-8}$  m
  - 100  $\mu\text{m}$
- Resolving power of scanning electron microscope is [DPMT 2007]
  - 5 – 20 nm
  - .01 nm
  - .1 nm
  - .0001
- Fluidity of bio-membranes can be shown by [DUMET 2009]
  - Electron microscope
  - Tissue culture
  - Phase-contrast microscope
  - Fluorescence microscope
- The dry weight of macromolecules like DNA, RNA and proteins can be determined using [Kerala PMT 2009]
  - Fluorescent microscopy
  - Dark field microscopy
  - Phase contrast microscopy
  - Differential interference contrast microscopy
  - Scanning electron microscopy
- The smallest size of a cell which can be seen with unaided eye is or differentiation capacity of human eye is [RPMT 1999]
  - 1 micron
  - 10 micron
  - 100 micron
  - 1000 micron
- Ultrastructure of cell can be best studied by [CBSE PMT 1999; MP PMT 2003; PET (Pharmacy) 2013]
  - Autoradiography
  - X-ray diffraction method
  - Phase contrast microscope
  - None of these
- Which one of the following statements is not true [Kerala PMT 2009]
  - Immersion oil increases the refractive index
  - Fluorescent microscopy uses the normal light to view molecules
  - Electron microscope has only electromagnetic lenses
  - Scanning tunneling microscope is useful in scanning computer chips for defects
  - Density gradient centrifugation can be used in the separation of cellular organelles

17. Electron microscope is based on principle of [WB JEE 2009]  
 (a) Electromagnetic theory  
 (b) Resolution of glass lenses  
 (c) Magnification of glass lenses  
 (d) Refraction of light
18. The resolving power of a compound microscope will increase with [WB JEE 2009]  
 (a) Decrease in wavelength of light and increase in numerical aperture  
 (b) Increase in wavelength of light and decrease in numerical aperture  
 (c) Increase in both wavelength of light and numerical aperture  
 (d) Decrease in both wavelength of light and numerical aperture
19. A major breakthrough in the study of cells came with the development of electron microscope. This is because [CBSE PMT 2006]  
 (a) Electron beam can pass through thick materials, whereas light microscopy requires thin sections  
 (b) The electron microscope is more powerful than the light microscope as it uses a beam of electrons which has wavelength much longer than that of photons  
 (c) The resolution power of the electron microscope is much higher than that of the light microscope  
 (d) The resolving power of the electron microscope is 200-350 nm as compared to 0.1-0.2 nm for the light microscope
20. With the increase in diameter of the rotor, the effective RCF (relative centrifugal force) at a fixed RPM (revolutions per minute) will [DUMET 2010]  
 (a) Remain unaffected  
 (b) Increase  
 (c) Decrease  
 (d) Be lower at the bottom of centrifuge tube
21. Electrons used in electron microscope are of the wavelength [WB JEE 2011]  
 (a) 0.05 Å (b) 0.15 Å  
 (c) 0.25 Å (d) 0.30 Å
22. Stain used by Feulgen to stain DNA is [MP PMT 2007]  
 (a) Janus green (b) Basic fuchsin  
 (c) Crystal violet (d) Methylene blue
23. Agarose extracted from sea weeds finds use in [CBSE PMT (Pre.) 2011]  
 (a) Gel electrophoresis (b) Spectrophotometry  
 (c) Tissue culture (d) PCR
24. The distribution of two or more specific molecules within a cell can be studied by using [Kerala PMT 2006]  
 (a) Dark field microscope  
 (b) Fluorescent microscope  
 (c) Phase contrast microscope  
 (d) Interference contrast microscope  
 (e) Bright field microscope
25. Microtome was developed by [MHCET 2001]  
 (a) Talbot (b) Brogy  
 (c) Merten (d) W. His
26. Which of the following techniques is used to extract proteins from the cell fractionation [AFMC 2012]  
 (a) Ultracentrifugation (b) Chromatography  
 (c) Autoradiography (d) Electrophoresis
27. Detailed structure of the membrane was studied after the advent of electron microscope during [NCERT; AMU (Med.) 2012]  
 (a) 1930's (b) 1950's  
 (c) 1970's (d) 1990's
28. Electron microscope is made up of [MP PMT 2004]  
 (a) Objective and ocular lenses  
 (b) Polarizer and analyzer filters  
 (c) Electromagnetic lenses  
 (d) Fluorochromes
29. In confocal microscope, the specimen is illuminated by [Odisha JEE 2004]  
 (a) UV ray (b) Laser beam  
 (c) Electron flow (d) None of these
30. One micrometer is a unit equivalent to [DPMT 2004; WB JEE 2012]  
 (a)  $10^{-3}$  m (b)  $10^{-6}$  m  
 (c)  $10^{-9}$  m (d)  $10^{-12}$  m
31. Which lenses in electron microscope are used to control and focus a [DPMT 2004]  
 (a) Convex lens (b) Concave lens  
 (c) Electric lens (d) Magnetic lens
32. Which of the following is used for observing spindle fibres [DPMT 2004]  
 Or  
 The microscope usually used for seeing living cells or tissues [AIIMS 2012]  
 (a) Dark field microscope  
 (b) Phase contrast microscope  
 (c) Polarisation microscope  
 (d) Scanning transmission electron microscope
33. Following technique uses radioactive precursors for observing metabolic activities of macromolecules, is [DPMT 2004]  
 Or  
 Which of the following technique, other than microscopy is used for study of cell [BHU 2004]  
 (a) Chromatography  
 (b) Density gradient centrifugation or cell fractionation  
 (c) Autoradiography  
 (d) Electron microscope
34. Numerical aperture of microscope lens is expressed by [WB JEE 2012]  
 (a) Angular aperture only  
 (b) Refractive index only  
 (c) Both angular aperture and refractive index  
 (d) Wave length of the light used

35. Which of the following is used for staining of lipids  
[Odisha JEE 2012]  
(a) Rhodamine (b) Iodine  
(c) Oil red O (d) Ethidium bromide
36. Pure fractions of cellular components can be isolated by  
[Kerala CET 2005]  
(a) Chromatography  
(b) Scanning electron microscopy  
(c) X-ray diffraction  
(d) Differential centrifugation  
(e) Autoradiography
37. Scientists were able to pinpoint the location of colour processing centres in the visual cortex of the brain by means of  
[Kerala PMT 2005]  
(a) PET (b) NMR  
(c) CT (d) X-ray  
(e) Ultra sound imaging
9. Cytosomes are found in [CBSE PMT 1993]  
(a) Chloroplasts (b) Bacteria  
(c) Mitochondria (d) All of these
10. Which of the following is seen only in prokaryotic cells  
[Kerala PMT 2012]  
(a) Dictyosome (b) Ribosome  
(c) Mesosome (d) Endoplasmic reticulum  
(e) DNA
11. Which of the following forms more than 1/2 of cell  
[AFMC 2001]  
(a) Water (b) Mineral  
(c) Protein (d) Carbohydrate
12. The smallest living cells with cell wall are [MP PMT 1994]  
Or  
Which of the following is a prokaryote  
[MP PMT 2007; Odisha JEE 2009]  
(a) Viroids (b) Algae  
(c) Bacteria (d) Mycoplasma

### Cell Introduction and Cell Theory

1. Who proposed the "Cell theory"  
MP PMT 1995, 96, 98, 2001, 05; CPMT 1998;  
AMU (Med.) 2001; BHU 2002; Kerala PMT 2002, 03;  
HP PMT 2005; AIIMS 2011; PET (Pharmacy) 2013]  
(a) Schleiden (botanist) and Schwann (zoologist)  
(b) Watson and Crick  
(c) Mendel and Morgan  
(d) Robert Hooke
2. Which of the following is the exception of cell theory  
[CMC Vellore 1993; BVP 2004; Kerala PMT 2004;  
Odisha JEE 2011; MP PMT 2011]  
(a) Bacteria (b) Fungi  
(c) Lichen (d) Virus
3. Difference between the prokaryotic and eukaryotic cells in having  
[AFMC 2002]  
(a) Cell wall (b) Nuclear membrane  
(c) Ribosome (d) None of these
4. Intracellular compartments are not found in cells of  
[MP PMT 1997]  
(a) Lower plants (b) Prokaryotes  
(c) Higher plants (d) Eukaryotes
5. How many types of cells are known [MP PMT 2000]  
(a) One (b) Two  
(c) Three (d) Four
6. The division of the plant kingdom into Prokaryota and Eukaryota is based on the characters of [MP PMT 1995, 98]  
(a) Nucleus only (b) Chromosomes only  
(c) Cell organelles only (d) All the above
7. T. Schwann and M. Schleiden were  
[CPMT 2001; BHU 2001]  
(a) Dutch biologists (b) English biologists  
(c) Austrian biologists (d) German biologists
8. Who proposed the theory that "cells arise only from the pre-existing cells" [AMU (Med.) 1993, 2010; MP PMT 1997]  
(a) Mohl (b) Virchow  
(c) Haeckel (d) Brown
13. Which of the following is absent in prokaryotes [KCET 2005]  
(a) DNA (b) RNA  
(c) Plasma membrane (d) Mitochondria
14. Which one of the following pairs is not correctly matched  
[MP PMT 1993]  
(a) Cristae The "Shelves" formed by the folding of the inner membrane of the mitochondrion  
(b) Plasmodesmata The membrane surrounding the vacuole in plants  
(c) Grana Membrane bound discs in chloroplasts that contain chlorophylls and carotenoids  
(d) Middle lamella Layer between adjacent cell walls in plants derived from cell plate
15. The branch which deals with the study of cell structure and function is known as  
[BHU 2000; MHCET 2000, 03; Pb. PMT 2004]  
(a) Histology (b) Ecology  
(c) Morphology (d) Cytology
16. Schleiden (1838) proposed that cell is the structural and functional unit of life. His idea was a [CPMT 2004]  
(a) Assumption (b) Generalization  
(c) Hypothesis (d) Observation
17. The cell organelles are found in [MP PMT 1996]  
(a) Bacterial cells (b) Cyanobacterial cells  
(c) Prokaryotic cells (d) Eukaryotic cells
18. The size of most of the cells is best expressed in [CPMT 1998]  
(a) Å (b) Millimeters (mm)  
(c) Nanometers (nm) (d) Micrometers (μm)
19. The word "Prokaryote" means a cell [JIPMER 1995]  
(a) With many nuclei (b) With one nucleus  
(c) With diffused nucleus (d) Without chloroplast

20. Robert Hooke used the term cell in the year [AFMC 1997; CPMT 2003; BHU 2004]  
(a) 1650 (b) 1665  
(c) 1865 (d) 1960
21. Which of the following is not a cell organelle [Bihar MDAT 1992; RPMT 2002]  
(a) Mitochondria (b) Ribosome  
(c) Golgi complex (d) Microsome
22. Which one is the largest unicellular organism [Kerala PMT 2004]  
(a) *Planaria* (b) *Volvox*  
(c) Blue green algae (d) Yeast  
(e) *Acetabularia*
23. Smallest known cell is [RPMT 1999]  
(a) *Acetabularia*  
(b) *Nostoc*  
(c) *Chlamydomonas*  
(d) *Pleuropneumonia like organism*
24. The cell theory states that [MP PMT 1995]  
(a) All cells have nuclei  
(b) All cells are totipotent  
(c) Cells reproduce by mitosis  
(d) Cells are the basic structural units of living beings
25. The main difference between plant and animal cell is [HP PMT 2005]  
(a) Animal cells lack cell wall  
(b) Plant cell has no cell wall  
(c) Animal cell has a rigid cell wall  
(d) Plant cells lack cell membrane
26. Match the following and choose the correct combination from the options given
- |    | Column I       |    | Column II                    |
|----|----------------|----|------------------------------|
| A. | Robert Hooke   | 1. | Mutation theory              |
| B. | Charles Darwin | 2. | Swan necked flask experiment |
| C. | Hugo de vries  | 3. | Origin of species            |
| D. | Louis pasteur  | 4. | Micrographia                 |
- [MH CET 2001; Kerala PMT 2004]  
(a) A-3, B-4, C-1, D-2 (b) A-2, B-1, C-3, D-4  
(c) A-1, B-2, C-3, D-4 (d) A-4, B-3, C-1, D-2  
(e) A-4, B-2, C-3, D-1
27. Which of the following is absent in prokaryotes [CPMT 1994; AIPMT 2015]  
(a) Nuclear membrane (b) Golgi bodies  
(c) Endoplasmic reticulum (d) All the above

### Cell wall

1. Which one of the following structures between two adjacent cells is an effective transport pathway [CPMT 1993; CBSE PMT 2009; CBSE PMT (Pre.) 2010]  
Or  
Cytoplasm of one cell is connected with other through [CPMT 1996; AFMC 1999; AIIMS 2003; DUMET 2010; Kerala PMT 2012]  
(a) Plasmalemma (b) Plasmodesmata  
(c) Plastoquinones (d) Endoplasmic reticulum
2. Middle lamella is made up of [NCERT; CPMT 1993; MP PMT 1995, 2011; MHCET 2001; CBSE PMT 2002, 09; AFMC 2003; DUMET 2009; Odisha JEE 2011]  
(a) Cellulose  
(b) Suberin  
(c) Calcium and magnesium pectate  
(d) Lignin
3. The internal layer joining the primary walls of the two adjacent cells is known as [MP PMT 1994]  
Or  
The possibility of being outermost layer of cell is highest for which of the following  
(a) Plasmodesmata (b) Middle lamella  
(c) Periderm (d) Casparian strip
4. The strength and rigidity of a cell wall is due to the substance known as [MP PMT 1994, 2006]  
(a) Suberin (b) Cellulose  
(c) Lignin (d) Pectin
5. The most abundant substance of middle lamella is [MP PMT 2013]  
(a) Suberin (b) Cutin  
(c) Lignin (d) Pectin
6. A mature plant cell has [MP PMT 1999, 2000]  
(a) Cell wall and protoplasm  
(b) Protoplasm and vacuole  
(c) Vacuole and cell wall  
(d) Protoplasm, cell wall and vacuole
7. Plant cell wall consists of [NCERT; CPMT 1995, 98; MP PMT 2013]  
(a) Lignin + hemicelluloses + pectin + lipid  
(b) Lipid + protein + hemicelluloses + pectin  
(c) Lignin + hemicelluloses + pectin + cellulose  
(d) Lignin + hemicelluloses + tubulin + cellulose
8. Identify the polysaccharide with  $\beta$ -glycosidic bonds [WB JEE 2012]  
(a) Starch (b) Glycogen  
(c) Sucrose (d) Cellulose
9. Cell wall is absent in [BVP 2000; MHCET 2001; MP PMT 2009, 13]  
(a) Gametes (b) *Amoeba*  
(c) Mycoplasma (d) All of these
10. The plant cell wall is made up of cellulose. This is believed to be [CPMT 1993; MP PMT 2002]  
(a) A liquid (b) A protein  
(c) A polysaccharide (d) An amino acid
11. A protoplast is a cell [AIPMT 2015]  
(a) Without nucleus  
(b) Undergoing division  
(c) Without cell wall  
(d) Without plasma membrane
12. What is the structural element of cell wall [WB JEE 2008]  
(a) Matrix (b) Microtubules  
(c) Microfibrils (d) Arabinogalactans

13. In the cell walls of the guard cells, cellulose microfibrils are oriented [AMU (Med.) 2009]  
(a) Radially (b) Transversely  
(c) Tangentially (d) Obliquely
14. The chemical substances found most abundantly in the middle lamella is released into the phragmoplast by [IEMCET 2009]  
(a) Endoplasmic reticulum (b) Golgi complex  
(c) Spindle fragments (d) Interzonal fibres
15. Which is correct for the structure of cell wall of bacteria and fungi [CPMT 1998; MHCET 2003]  
(a) Both are made up of cellulose  
(b) Both have mucopeptide  
(c) Both are made up of N-acetylglucosamine  
(d) None of these
16. In plants, both cellulose and hemicellulose are major components of which one of the following [WB JEE 2016]  
(a) Plasma membrane (b) Cell wall  
(c) Nuclear membrane (d) Mitochondrial membrane
7. Lipid molecule in plasma membrane are arranged in [CPMT 2002; RPMT 2005]  
(a) Scattered (b) Series  
(c) Alternate (d) Head parallel
8. Select of correct statement from the following regarding cell membrane [CBSE PMT (Pre.) 2012]  
**Or**  
Who proposed "fluid mosaic model" for plasma membrane [NCERT; RPMT 1999, 2006; BHU 2000, 01; Pb. PMT 2004; Odisha JEE 2004, 11; DPMT 2006; J & K CET 2010; MP PMT 2011]  
(a)  $\text{Na}^+$  and  $\text{K}^+$  ions move across cell membrane by passive transport  
(b) Proteins make up 60 to 70% of the cell membrane  
(c) Lipids are arranged in a bilayer with polar heads towards the inner part  
(d) Fluid mosaic model of cell membrane was proposed by Singer and Nicolson
9. Ion carriers are located in [KCET 2000]  
(a) Nucleus (b) Cell wall  
(c) Cellular space (d) Plasma membranes
10. The type of cell junction which facilitates cell to cell communication is [Kerala PMT 2008; AIPMT 2015]  
(a) Tight junction (b) Adhering junction  
(c) Gap junction (d) Desmosomes  
(e) Brush borders
11. Desmosomes are concerned with [CBSE PMT 1995; AIIMS 2010]  
(a) Cell division (b) Cellular excretion  
(c) Cytolysis (d) Cell adherence
12. On which surface of cell Donnan equilibrium occur [GUJCET 2015]  
**Or**  
Desmosome is a modification of [MP PMT 2004]  
(a) Cell wall (b) Tonoplast  
(c) Plasma membrane (d) Nuclear membrane

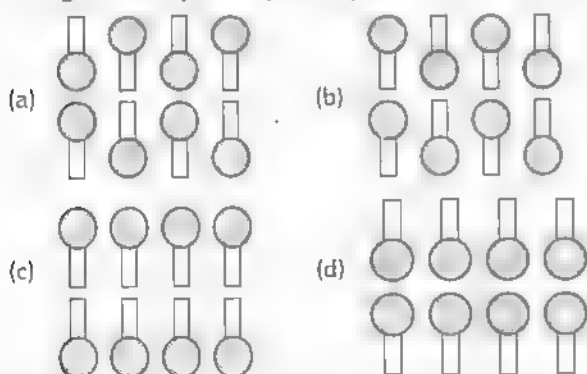
### Plasma Membrane

1. The plasma membrane consists mainly of [MP PMT 1996, 97, 2001, 12; CBSE PMT 2002; Odisha JEE 2008, 11; CBSE PMT (Pre.) 2010]  
(a) Proteins embedded in a carbohydrate bilayer  
(b) Phospholipids embedded in a protein bilayer  
(c) Proteins embedded in a phospholipid bilayer  
(d) Proteins embedded in a polymer of glucose molecules
2. For cell membrane, name "plasmalemma" was given by [CPMT 2010]  
(a) Porter (b) Nageli  
(c) Cramer (d) Plowe
3. Most abundant Lipid in cell membrane is [Odisha JEE 2008; WB JEE 2011]  
(a) Phospholipid (b) Starch  
(c) Oil (d) Sulpholipid
4. Beet root if kept in cold water anthocyanin does not come out due to plasma membrane [BHU 2003]  
(a) Differentially permeable  
(b) Impermeable to anthocyanins  
(c) Permeable to anthocyanins  
(d) Dead
5. Which of the following layer is present nearest to plasma membrane in plant cell [AFMC 2002]  
(a) Secondary wall (b) Middle lamella  
(c) Primary wall (d) Tonoplast
6. Keeping in view the fluid mosaic model for the structure of cell membrane, which one of the following statements is correct with respect to the movement of lipids and proteins from one lipid mono layer to the other (described as flip flop movement) [CBSE PMT 2008, 09]  
(a) While proteins can flip-flop, lipids can not  
(b) Neither lipids, nor proteins can flip-flop  
(c) Both lipids and proteins can flip-flop  
(d) While lipids can rarely flip-flop, proteins can not
13. According to the 'Unit membrane model' the thickness of the cell membrane is about [MP PMT 1994]  
(a) 200 nm (b) 7.5 nm  
(c) 150 nm (d) 1.0 nm
14. Which of the following does not require carrier molecules during transport through cell membranes [BHU 1994; WB JEE 2008]  
(a) Simple diffusion  
(b) Facilitated diffusion  
(c)  $\text{Na}^+ - \text{K}^+$  transport  
(d) Active transport of sugars and amino acids
15. Which of the following structures controls the transport of the material into and out of living cells or controls permeability [BHU 1999; Odisha JEE 2005]  
**Or**  
Which one of the following does not differ in *E. coli* and *Chlamydomonas* [CBSE PMT (Pre.) 2012]  
(a) Centrosome (b) Cell membrane  
(c) Cell wall (d) Ribosome

16. In eubacteria, a cellular component that resembles eukaryotic cell is [CBSE PMT (Pre.) 2011]  
 (a) Cell wall (b) Plasma membrane  
 (c) Nucleus (d) Ribosomes
17. Which of the following constituent of biological membrane [MP PMT 2002, 03; AIEEE Pharmacy 2004]  
 (a) Phosphoprotein (b) Protein and Phospholipid  
 (c) Phospholipids (d) Cellulose
18. Plasma membrane helps in [J & K CET 2005]  
 (a) Transportation of only water in and out of cell  
 (b) Protein synthesis  
 (c) Osmoregulation  
 (d) Nucleic acid synthesis
19. The non-membranous structure is [DPMT 2004]  
 (a) Centrioles (b) Ribosomes  
 (c) Nucleolus (d) All of these
20. Single membrane bound organelles are [CBSE PMT 1999; DPMT 2004]  
 (a) Lysosome (b) Sphaerosome  
 (c) Glyoxysome (d) All of these
21. Which one of the following is not a constituent of cell membrane [CBSE PMT 2007]  
 (a) Cholesterol (b) Glycolipids  
 (c) Proline (d) Phospholipids
22. The cell membranes of adjacent cells are fused at this cell junction [AMU (Med.) 2010, 12]  
 (a) Macula adherens (b) Zonula adherens  
 (c) Zonula occludens (d) Nexus
23. In the given figure, the lipid molecules present in plasma membrane have polar heads and non - polar tails



Which of the following figure represents the correct arrangement of lipids in lipid bilayer [NCERT]



24. Bulk drinking of fluid by cells is termed as [CBSE PMT 1993; CPMT 2000]  
 Or

The process of sucking of fluid from the cell surface is called [RPMT 1999]

- (a) Phagocytosis (b) Pinocytosis  
 (c) Cyclosis (d) Osmosis

25. Thickness of plasma membrane is [MP PMT 2003, 09]  
 (a) 10 Å to 30 Å (b) 30 Å to 50 Å  
 (c) 50 Å to 70 Å (d) 70 Å to 100 Å
26. The process of cell eating is called [KCET 2000]  
 (a) Pinocytosis (b) Phagocytosis  
 (c) Endocytosis (d) Exocytosis
27. According to widely accepted "Fluid mosaic model" cell membranes are semi-fluid, where lipids and integral proteins can diffuse randomly. In recent years, this model has been modified in several respects. In this regard, which of the following statements is incorrect [NCERT; CBSE PMT 2005]  
 (a) Proteins in cell membranes can travel within the lipid bilayer  
 (b) Proteins can also undergo flip-flop movements in the lipid bilayer  
 (c) Proteins can remain confined within certain domains of the membrane  
 (d) Many proteins remain completely embedded within the lipid bilayer
28. Which is the latest model that is proposed to explain the structure of plasma membrane [BHU 2001; CBSE PMT 2002; BVP 2003]  
 (a) Fluid mosaic model (b) Molecular model  
 (c) Unit membrane model (d) None of the above
29. According to mosaic model, plasma membrane is made up of  
 (a) Cellulose and hemicellulose  
 (b) Phospholipid and integrate protein  
 (c) Phospholipid, extrinsic and intrinsic protein  
 (d) Phospholipid and hemicellulose
30. Lomasomes are found in [BVP 2000]  
 (a) Algal cell (b) Fungal cell  
 (c) Yeast (d) E. coli
31. Singer and Nicholson's model of plasma membrane differs from Robertson's model in the  
 (a) Number of lipid layers  
 (b) Arrangement of lipid layers  
 (c) Arrangement of proteins  
 (d) Absence of protein in Singer and Nicholson's model
32. Carbohydrates are present in the plasmalemma in the form of  
 (a) Starch  
 (b) Cellulose  
 (c) Hemicellulose  
 (d) Phospholipids (glycolipids) and phosphoproteins (glycoproteins)
33. Match the following items in column-I with those in column-II and choose the correct answer [WB JEE 2016]

Column-I		Column-II	
P.	Plasma membrane mainly contains	i.	Hemicellulose
Q.	Middle lamella mainly composed of	ii.	Calcium pectate
		iii.	Proteinaceous filaments
		iv.	Proteins embedded in phospholipid bilayer

- (a) P-ii, Q-i (b) P-i, Q-ii  
 (c) P-iv, Q-ii (d) P-iii, Q-iv



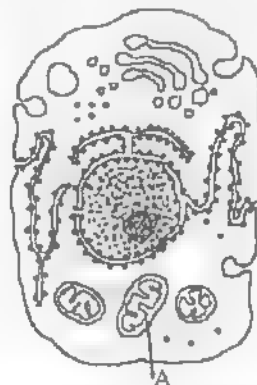
## Protoplasm and Cytoplasm

- The name 'protoplasm' was given by  
[CPMT 1994; MP PMT 1999, 2000; MHCET 2001;  
Pb. PMT 2004; J & K CET 2005]  
(a) Purkinje (b) Hooke  
(c) A.K. Sharma (d) Schwann
- Both plants and animals are provided with [KCET 1998]  
(a) Cell wall (b) Golgi body  
(c) Chloroplast (d) Protoplasm
- Ribonucleoprotein particles of protoplasm are [RPMT 2006]  
(a) Ribosomes (b) Plastid  
(c) Golgi body (d) Cristae
- The amount of which of the element is greatest in protoplasm [RPMT 1997, 99]  
(a) Hydrogen (b) Oxygen  
(c) Nitrogen (d) Carbon
- Normal pH of Protoplasm is [RPMT 1999]  
(a) 7.8 (b) 6.8  
(c) 5 (d) 6.5
- Cyclosis is [KCET 1994; RPMT 1997]  
(a) Circular movement of cytoplasm inside the cell  
(b) Up and down movement of protoplasm  
(c) To and fro movement of nucleoplasm  
(d) None of the above
- The term 'cytoplasm' and 'nucleoplasm' were given by [KCET 2007]  
(a) Purkinje (b) Strasburger  
(c) Brown (d) Flemming
- In higher plants, continuity of cytoplasm from one cell to its neighbouring cells is established through [WB JEE 2012]  
(a) Apoplast (b) Chloroplast  
(c) Leucoplast (d) Symplast
- Protoplasm is a [Pune CET 1998]  
(a) True solution (b) Suspension  
(c) Emulsion (d) Polyphasic colloidal system
- The substance which makes up about 80% of cytoplasm and has unique structure [Kerala CET 2002]  
(a) Proteins (b) Fats  
(c) Minerals (d) Water
- The main arena of various types of activities of a cell is [CBSE PMT (Pre.) 2010]  
**Or**  
Proteins required for functioning of nucleus are formed in [BHU 2012]  
(a) Nucleus (b) Plasma membrane  
(c) Mitochondrion (d) Cytoplasm
- Protein synthesis in an animal cell, takes place [CBSE PMT 1997]  
(a) Only in the cytoplasm  
(b) In the cytoplasm as well as in mitochondria  
(c) In the nucleolus as well as in the cytoplasm  
(d) Only on ribose attached to nucleon

- Protoplasm was regarded as the "physical basis of life" by [Odisha JEE 1992; BHU 1992; CPMT 1993; MP PMT 1999; BVP 2000]  
(a) Huxley (1868) (b) Corti (1772)  
(c) Hardy (1899) (d) Malpighi (1903)

## Mitochondria

- Who observed the "mitochondria" first [PET (Pharmacy) 2013]  
(a) Kolliker (b) Robert Brown  
(c) Robert Hooke (d) Altmann
- Select the alternative giving correct identification and function of the organelle 'A' in the diagram

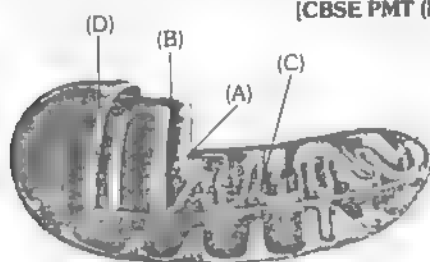


- [NEET (Karnataka) 2013]
- Mitochondria – produce cellular energy in the form of ATP
  - Golgi body – provides packaging material
  - Lysosomes – secrete hydrolytic enzymes
  - Endoplasmic reticulum – synthesis of lipids
- Mitochondria perform all of the following functions except [AFMC 2008]  
(a) Nucleic acid synthesis  
(b)  $\beta$  – oxidation of fatty acids  
(c) ATP synthesis  
(d) Polysaccharide degradation
  - In mitochondria, protons accumulate in the [CBSE PMT (Mains) 2011]  
(a) Intermembrane space (b) Matrix  
(c) Outer membrane (d) Inner membrane
  - Prokaryotic origin of mitochondria was proposed by [Pune CET 1998]  
(a) Rabinowitch (b) Altmann and Schimper  
(c) Salton (d) Morrison
  - Mitochondria are related to [MP PMT 1999]  
(a) Prokaryotes (b) Plasmids  
(c) Plastids (d) Viruses
  - $F_1$  particles / oxysome/ elementary particles are present in [RPMT 1995; PUNE CET 1998; CPMT 1999; AFMC 1999; JIPMER 2001; MP PMT 2002; MHCET 2004; Odisha JEE 2004; AIEEE Pharmacy 2004]  
(a) Endoplasmic reticulum (b) Chloroplast  
(c) Mitochondria (d) Golgi complex
  - The number of mitochondria increases in cells of [MP PMT 1997]  
(a) Dormant seeds (b) Germinating seeds  
(c) Dry seeds (d) Dead seeds

9. In prokaryotes, the mitochondria are absent. Even then Krebs's cycle takes place. What is the site of Krebs's cycle in bacteria [Bihar MDAT 1995]

(a) Ribosomes (b) Nucleoid  
(c) Cytoplasm (d) Mesosomes

10. The figure below shows the structure of a mitochondrion with its four parts labelled (A), (B), (C) and (D). Select the part correctly matched with its function [CBSE PMT (Mains) 2011]



- (a) Part (C) : Cristae – possess single circular DNA molecule and ribosomes  
(b) Part (A) : Matrix – major site for respiratory chain enzymes  
(c) Part (D) : Outer membrane – gives rise to inner membrane by splitting  
(d) Part (B) : Inner membrane – forms infoldings called cristae
11. What is mitoplast [WB JEE 2010]  
(a) Membraneless mitochondria  
(b) Another name of mitochondria  
(c) Mitochondria without outer membrane  
(d) Mitochondria without inner membrane
12. Racker's particles are found in [Manipal 2005]  
Or  
Fernandez Morgan particles are seen in [Odisha JEE 2012]  
(a) Chromosome (b) Mitochondria  
(c) Nucleus (d) Golgi body
13. Folding of inner membrane of mitochondria are called [MHCET 2004; MP PMT 2004, 05; Kerala PMT 2010]  
(a) Cristae (b) Grana  
(c) Calcium oxalate crystals (d) Sacs
14. Organelles which are regarded as 'Power house' of the cell and in which the oxidative reactions of the respiratory process takes place are [KCET 1994, 2004; Bihar MDAT 1995; CPMT 2001, 02; MP PMT 2003, 04; RPMT 2005; AFMC 2009]  
Or  
Which of the following cell organelles is responsible for extracting energy from Carbohydrates to form ATP [NEET 2017]  
(a) Chloroplast (b) Ribosomes  
(c) Endoplasmic reticulum (d) Mitochondria
15. Who first introduced the term 'mitochondrion' [KCET 1999; Pb. PMT 2004]  
(a) Kolliker (b) Robert Brown  
(c) Benda (d) Altman

16. Which of the following cell organelle is considered to be rich in catabolic enzymes [Pb. PMT 1999; MP PMT 2002, 13; CPMT 2002; DPMT 2003]

Or

Respiratory and oxidative enzymes are present in [AFMC 1995; CPMT 2001]

Or

Highest number of enzyme is found in [MP PMT 2007]

- (a) Endoplasmic reticulum (b) Lysosome  
(c) Golgi body (d) Mitochondria
17. In which of the following parts of mitochondria, succinic dehydrogenase enzyme is located [MP PMT 2012]

Or

In mitochondria, enzyme cytochrome oxidase is present in [MP PMT 2009]

- (a) Outer membrane (b) Inner membrane  
(c) Perimitochondrial space (d) Matrix
18. The cristae of mitochondria possess [MHCET 2002]  
(a) Oxyosomes (b) Peroxisomes  
(c) Nucleosomes (d) Quantasomes
19. Mitochondria are non-existent in [MP PMT 1994, 2011]  
(a) Red algae (b) Some bacteria  
(c) Green algae (d) Brown algae
20. Mitochondria supply most of the necessary biological energy by [MP PMT 1994]  
(a) Breaking down of sugar  
(b) Oxidizing substrates of TCA cycle  
(c) Reducing NADP  
(d) Breaking down of protein
21. The size of mitochondria in plant cell is [AMU (Med.) 2010]  
(a) 0.1–1.0  $\mu\text{m}$  long (b) 1.0–4.0  $\mu\text{m}$  long  
(c) 2.0–4.0  $\mu\text{m}$  long (d) 3.0–4.0  $\mu\text{m}$  long
22. Which of the following statements regarding mitochondrial membrane is not correct [CBSE PMT 2006]  
(a) The inner membrane is highly convoluted forming a series of infoldings  
(b) The outer membrane resembles as sieve  
(c) The outer membrane is permeable to all kinds of molecules  
(d) The enzymes of the electron transfer chain are embedded in the outer membrane
23. Which one of the following human cells does not contain mitochondria [WB JEE 2011]  
(a) Nerve cell (b) Red blood cell  
(c) Liver cell (d) White blood cell
24. Autonomic genome system is present in [MP PMT 2000]  
(a) Ribosomes and chloroplasts  
(b) Mitochondria and ribosomes  
(c) Mitochondria and chloroplasts  
(d) Golgi bodies and mitochondria

25. The presence of DNA in mitochondria and chloroplast supports the hypothesis that [J & K CET 2002]  
(a) Mitochondria and chloroplast both originated as independent free living organisms  
(b) Glycolysis occurs in mitochondria and chloroplast both  
(c) ATP is produced in mitochondria and chloroplast both  
(d) Mitochondria and chloroplast undergo meiosis and mitosis independent of nucleus
26. Centre of phosphorylation [AFMC 2000]  
(a) Peroxisome (b) Oxisome  
(c) Ribosome (d) Mitochondria
27. In which part of mitochondria, ATP is generated [HPMT 1999; BHU 2003; CPMT 2010]  
(a) Matrix (b) Cristae  
(c) Outer membrane (d)  $F_1$  particles (oxysomes)
28. The reaction of ATP formation is  
(a) Exergonic (b) Endergonic  
(c) Spontaneous (d) Reversible
29. Identify the membrane across which the proton ( $H^+$ ) gradient facilitates ATP synthesis in a typical eukaryotic cell [WB JEE 2012]  
(a) Plasma membrane  
(b) Mitochondrial inner membrane  
(c) Mitochondrial membrane  
(d) Nuclear membrane
30. Mitochondria are semi autonomous as they possess [WB JEE 2010]  
(a) DNA (b) DNA + RNA  
(c) DNA + RNA + ribosomes (d) Protein
31. Which of the following is correct pair [CBSE PMT 1993]  
(a) DNA synthesis — Ribosomes  
(b) Protein synthesis — Smooth E.R.  
(c) Aerobic respiration — Cristae  
(d) Suicidal sacs — Dictyosomes
32. Mitochondria are the site for [MP PMT 1996]  
(a) Photophosphorylation (b) Oxidative phosphorylation  
(c) Transpiration (d) Carboxylation

### Plastids

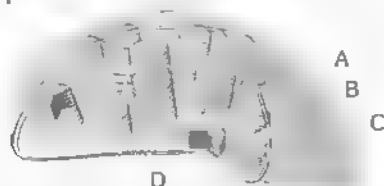
1. Cell organelles found only in plants [MP PMT 2001]  
(a) Golgi complex (b) Mitochondria  
(c) Plastids (d) Ribosomes
2. Green pigment (Chlorophyll) present in plants is [AFMC 2002; MP PMT 2005]  
(a) Chromoplast (b) Chloroplast  
(c) Ribosome (d) Lysosome
3. The bright colours of ripe fruits are due to [AIIEE Pharmacy 2003]  
**Or**  
Which of the following type of plastids does not contain stored food material [NEET (Karnataka) 2013]  
(a) Leucoplasts (b) Chloroplasts  
(c) Amyloplasts (d) Chromoplasts
4. Plant cell differ from animal cell because of [MP PMT 2003]  
(a) The presence of cell wall and absence of chlorophyll in plant cell  
(b) The presence of cell wall and chlorophyll in plant cell  
(c) The absence of cell wall and presence of chloroplast in animal cell  
(d) The absence of cell wall and presence of chlorophyll in plant cell
5. In which plastids are not found [MP PMT 2000]  
(a) Blue green algae (b) Bacteria  
(c) Fungi (d) All of the above
6. Which of the following organelles is bounded by two unit membranes [Pune CET 1998]  
(a) Golgi complex (b) Peroxisome  
(c) Chloroplast (d) Lysosome
7. What is common between chloroplasts, chromoplasts and leucoplasts [AIIMS 2008]  
(a) Presence of pigments  
(b) Possession of thylakoids and grana  
(c) Storage of starch, proteins and lipids  
(d) Ability to multiply by a fission-like process
8. Which one of the following cellular parts is correctly described [MP PMT 1997; Odisha JEE 2004; CBSE PMT (Malna) 2012; AIPMT (Cancelled) 2015]  
(a) Thylakoids-flattened membranous sacs forming the grana of chloroplasts  
(b) Centrioles-sites for active RNA synthesis  
(c) Ribosomes-those on chloroplasts are larger (80s) while those in the cytoplasm are smaller (70s)  
(d) Lysosomes-optimally active at a pH of about 8.5
9. Thylakoids are constituents of [MP PMT 1997; WB JEE 2010]  
(a) Chloroplasts (b) Mitochondria  
(c) ER (d) Ribosomes
10. In higher plants, the shape of the chloroplast is [DUMET 2009; MH CET 2015]  
(a) Discoid (Lens) (b) Cup-shaped  
(c) Girdle-shaped (d) Reticulate
11. From the following, select the statement that is true [J & K CET 2012]  
(a) All cells have a cell wall  
(b) Animal cells contain microtubules but plant cells do not contain microtubules  
(c) The Golgi apparatus is found only in animal cells  
(d) Chloroplasts are found in plant cells but not in prokaryotic or animal cells
12. The chloroplasts of algae usually lack [MP PMT 1994]  
(a) Grana (b) Pigments  
(c) Quantasomes (d) Lamellae
13. Aleuroplasts in a cell store [AMU (Med.) 2010]  
(a) Starch (b) Oil  
(c) Protein (d) Nutrients
14. Plant cells differ from animal cells in having [MP PMT 1995, 98]  
(a) Centrosome (b) Golgi body  
(c) Vacuole (d) Plastid
15. Select the wrong statement from the following [CBSE PMT 2007]  
(a) Both chloroplasts and mitochondria contain an inner and an outer membrane  
(b) Both chloroplasts and mitochondria have an internal compartment, the thylakoid space bounded by the thylakoid membrane  
(c) Both chloroplasts and mitochondria contain DNA  
(d) The chloroplasts are generally much larger than mitochondria

16. In chloroplasts, chlorophyll is present in the [CBSE PMT 2004, 05]  
 (a) Thylakoids (b) Stroma  
 (c) Outer membrane (d) Inner membrane
17. The term chromatophore was coined by [AIIMS 1998]  
 (a) Schmitz (b) Comparethi  
 (c) W. Pfeffer (d) Singer and Nicolsan
18. Quantasomes are found in [RPMT 2005; HPMT 2005; MP PMT 2009, 11]  
 (a) Mitochondria (b) Chloroplast  
 (c) Lysosome (d) Endoplasmic reticulum
19. The main difference between chlorophyll 'a' and 'b' is  
 (a) Chlorophyll 'a' is linear chain compound and 'b' is branched chain  
 (b) Chlorophyll 'a' has no  $Mg^{+}$  ion in centre of molecule  
 (c) In chlorophyll 'a' there is  $CH_3$  group whereas in 'b' it is -CHO group  
 (d) All of the above
20. In land plants the guard cells differ from other epidermal cells in having [CBSE PMT (Pre.) 2011]  
 (a) Chloroplasts (b) Cytoskeleton  
 (c) Mitochondria (d) Endoplasmic reticulum
21. Match Column - I with Column - II and select the correct option

Column - I (Type of Chloroplast)		Column - II (Algae)	
A.	Cup shaped	1.	<i>Ulothrix</i>
B.	Girdle shaped	2.	<i>Oedogonium</i>
C.	Stellate	3.	<i>Chlamydomonas</i>
D.	Reticulate	4.	<i>Zygnema</i>

[Kerala PMT 2007]

- (a) A-2, B-4, C-3, D-1 (b) A-3, B-1, C-4, D-2  
 (c) A-3, B-4, C-2, D-1 (d) A-4, B-3, C-1, D-2  
 (e) A-3, B-4, C-1, D-2
22. Water soluble yellowish pigment present in petals of Dahlia is [MP PMT 2004]  
 (a) Carotene (b) Xanthophyll  
 (c) Anthoxanthin (d) Anthocyanin
23. Examine the section view of chloroplast showing the different parts



In which of the following options all the four blanks A, B, C and D are correctly identified [NCERT]

- (a) A - Granum, B - Thylakoid, C - Stroma, D - Stromal lamella  
 (b) A - Thylakoid, B - Granum, C - Stromal lamella, D - Stroma  
 (c) A - Granum, B - Thylakoid, C - Stromal lamella, D - Stroma  
 (d) A - Thylakoid, B - Stromal lamella, C - Stroma, D - Granum

24. Stroma is the ground material of which of the following [MP PMT 2004]  
 (a) Lysosomes (b) Ribosomes  
 (c) Chloroplasts (d) Mitochondria
25. The amyloplasts look like [AFMC 1997]  
 (a) Proplastids (b) Elaioplast  
 (c) Aleuroplast (d) Chloroplast
26. Which of these is mis-match [DPMT 2007; Kerala PMT 2007, 09, 10; AFMC 2008; CPMT 2010]  
 (a) Amyloplasts - Store protein granules  
 (b) Elaioplasts - Store oils or fats  
 (c) Chloroplasts - Contain chlorophyll pigments  
 (d) Chromoplasts - Contain coloured pigments other than chlorophyll  
 (e) Leucoplasts - Contain colourless pigment
27. Red colour of tomato is due to [Odisha JEE 2004; MP PMT 2011]  
 (a)  $\beta$ -carotene (b) Anthocyanin  
 (c) Lycopene (d) Erythrocyanin
28. When green tomatoes fruits turn to red, then [AFMC 2003]  
 (a) Chloroplasts are disintegrated and get converted into chromoplasts  
 (b) New chromoplasts are formed  
 (c) Chromoplasts are changed to chloroplasts  
 (d) None of the above
29. Extranuclear DNA in the cytoplasm is found inside [CPMT 1994; AFMC 2012]  
 (a) Chloroplast/Mitochondria (b) Ribosome  
 (c) Endoplasmic reticulum (d) Golgi apparatus
30. All plastids have essentially same structure because [CBSE PMT 1994]  
 (a) They have to perform same function  
 (b) They are localized in aerial parts of plant  
 (c) All plastids store starch, lipid and proteins  
 (d) One type of plastids can be differentiated into another type of plastid depending on cell requirements
31. Chromoplast may be of [CPMT 1994]  
 (a) Orange colour (b) Red colour  
 (c) Yellow colour (d) All the above
32. The thylakoid in chloroplast are arranged as [BHU 2003]  
 (a) Interconnected disc (b) Interconnected sacs  
 (c) Stacked discs (d) None of these
33. Many cells function properly and divide mitotically even though they do not have [AIIMS 2005]  
 (a) Plasma membrane (b) Cytoskeleton  
 (c) Mitochondria (d) Plastids

### Endoplasmic reticulum and Golgi body

1. Which of the following is a part of endomembrane system of eukaryotic cell [J & K CET 2008]  
 (a) Peroxisomes (b) Chloroplasts  
 (c) Mitochondria (d) Golgi complexes
2. Which type of membrane is most abundant within a cell [WB JEE 2008]  
 (a) ER membrane (b) Nuclear membrane  
 (c) Golgi membrane (d) Plasma membrane

3. The transfer vesicle from RER fuse with which region of golgi complex [CPMT 2000]

(a) Cis (b) Medial  
(c) Trans (d) Protein arms

4. Nuclear envelope is a derivative of [AIPMT (Cancelled) 2015]

(a) Membrane of Golgi complex  
(b) Microtubules  
(c) Rough endoplasmic reticulum  
(d) Smooth endoplasmic reticulum

5. Endoplasmic reticulum is more developed in [MP PMT 1999]

(a) Green cells (b) Young cells  
(c) Mature cells (d) Bacteriophage

6. An interconnecting membranous network of the cell composed of vesicles, flattened sacs and tubules is [KCET 2012]

Or

Nuclear membrane is formed around the groups of daughter chromosomes during the telophase by [WB JEE 2016]

(a) Nucleus (b) Mitochondrion  
(c) Endoplasmic reticulum (d) Lysosome

7. See the figure and identify it [NCERT]

C.isternae



(a) RER (b) GB  
(c) SER (d) None

8. Important site for formation of glycoproteins and glycolipids is [NCERT; CBSE PMT (Pre.) 2011]

(a) Lysosome (b) Vacuole  
(c) Golgi apparatus (d) Plastid

9. The most important function of endoplasmic reticulum is [DPMT 1993; HPMT 2005]

(a) Protein synthesis (b) Nourishing the nucleus  
(c) Secretion of materials (d) To give shape to the cell

10. In rapidly dividing cells, endoplasmic reticulum is [MP PMT 1994]

(a) Highly developed (b) Poorly developed  
(c) Absent (d) Non-functional

11. Main function of dictyosomes is [CPMT 2005]

(a) Respiration (b) Storage  
(c) Secretion (d) Breakdown of fats

12. In endoplasmic reticulum the following process take place [MP PMT 2001]

(a) Lipid synthesis  
(b) Channeling of biosynthetic processes  
(c) Steroid synthesis  
(d) All of the above

13. Mechanical support, enzyme circulation, protein synthesis and detoxification of drugs are function of [AIIMS 1999; CBSE PMT 2000, 05; AFMC 2006; BHU 2008]

Or

Which of the following is related to glycosylation of protein [CBSE PMT 2000]

(a) ER (b) Ribosomes  
(c) Dictyosomes (d) Chloroplast

14. The endoplasmic reticulum often bears [MP PMT 1994; J & K CET 2005]

(a) Lysosomes (b) Centrioles  
(c) Peroxisomes (d) Ribosomes

15. When the region of endoplasmic reticulum are studded by ribosome on their outer surface of the cisternae, it is called [Pb. PMT 1999; AIIMS 2000]

(a) Sarcoplasmic reticulum  
(b) Smooth endoplasmic reticulum  
(c) Granular endoplasmic reticulum  
(d) None of the above

16. The cisternae that make up the Golgi complex are [MP PMT 2013]

(a) Rough (b) Polarized  
(c) Non-polarized (d) Reticulate

17. The endoskeleton of cell is made up of [AIEEE Pharmacy 2003; DPMT 2003; BVP 2004; PET (Pharmacy) 2013]

(a) Cell wall (b) Endoplasmic reticulum  
(c) Cytoplasm (d) Mitochondria

18. "Endoplasmic reticulum" was discovered by [MP PMT 2000]

(a) Porter (b) Altmann  
(c) Golgi (d) Benda

19. RER is mainly concerned with [RPMT 1999]

(a) Proteolysis (b) Fatty acids synthesis  
(c) Peptide bond formation (d) Cholesterol synthesis

20. Which organelle is present in higher number in secretory cells [MP PMT 2007]

Or

One of the following serves as a temporary storage place for proteins and other compounds synthesized by endoplasmic reticulum [AFMC 1993]

(a) Dictyosome (b) ER  
(c) Lysosome (d) Vacuole

21. Endoplasmic reticulum is in continuation with [BHU 2005; CPMT 2009]

(a) Golgibody (b) Nuclear wall  
(c) Mitochondria (d) Cell wall

22. Golgi body originated from [CPMT 2002; AFMC 2003; RPMT 2005]

(a) Lysosome (b) Endoplasmic reticulum  
(c) Mitochondria (d) Cell membrane

23. Which is not function of golgibody [RPMT 1999]

(a) Secretion  
(b) Formation of plasmamembrane  
(c) Fat synthesis  
(d) Cell wall formation

24. Which of the following is the site of lipid synthesis [NCERT; Kerala CET 2002; RPMT 2006; AMU (Med.) 2009; NEET 2013; AIIMS 2013; AIPMT (Cancelled) 2015]

(a) Rough ER (b) Smooth ER  
(c) Golgi bodies (d) Ribosome

25. In plant cells the number of golgi bodies increases during [MP PMT 1997]

(a) Cell division (b) Food synthesis  
(c) Translocation (d) Respiration

26. The golgi apparatus contains [AIIMS 1993]

(a) DNA  
(b) RNA  
(c) Phospholipids, proteins, enzymes and vitamin C  
(d) Protein-lipid-protein.

27. Identify the components labelled A, B, C and D in the diagram below from the list (i) to (viii) given along with [NCERT]



#### Components:

- (i) Cristae of mitochondria  
(ii) Inner membrane of mitochondria  
(iii) Cytoplasm  
(iv) Smooth endoplasmic reticulum  
(v) Rough endoplasmic reticulum  
(vi) Mitochondrial matrix  
(vii) Cell vacuole  
(viii) Nucleus

The correct components are

[CBSE PMT (Main) 2010; NEET 2013]

	A	B	C	D
(a)	(v)	(iv)	(viii)	(iii)
(b)	(i)	(iv)	(viii)	(vi)
(c)	(vi)	(v)	(iv)	(vii)
(d)	(v)	(i)	(iii)	(ii)

28. Golgi bodies are absent in [MP PMT 1999]

(a) Plants (b) Bacteria  
(c) Animals (d) Eukaryotic cells

29. The Golgi complex plays a major role [CPMT 1996; NEET 2013]

(a) In post translational modification of proteins and glycosidation of lipids  
(b) In trapping the light and transforming it into chemical energy  
(c) In digesting proteins and carbohydrates  
(d) As energy transferring organelles

30. Secretory and membrane proteins are processed in [CPMT 2000; MP PMT 2003]

(a) Peroxisomes (b) Glyoxysomes  
(c) Golgi complex (d) Sphaerosomes

## Lysosome and Ribosomes

1. "Lysosomes" were discovered by [Kashmir MEE 1995; CPMT 1996; MP PMT 2003; Odisha JEE 2008]

(a) Haekel (b) De Duve  
(c) De Vries (d) Purkinje

2. Which of the following statements is incorrect with reference to lysosomes [JIPMER 2002]

(a) They are filled acid hydrolase and other enzymes  
(b) They are monomorphic and uniform in structure and function  
(c) They may be autophagic  
(d) They can digest proteins, nuclei acids, lipids and polysaccharides

3. The element responsible for the ring structure of chlorophyll and maintenance of ribosome structure is [KCET 2015]

(a)  $Ca^{++}$  (b)  $Mg^2$   
(c) S (d)  $K^+$

4. The two sub-units of ribosome remain united at a critical ion level of [RPMT 2001; CBSE PMT 2008]

(a) Magnesium (b) Calcium  
(c) Copper (d) Manganese

5. What would happen if lysosomes get ruptured inside the cells in which they are present [MP PMT 1997]

(a) Cells will swell (b) Cells will shrink  
(c) Cells will die (d) Nothing would happen

6. Three of the following statements regarding cell organelles are correct while one is wrong. Which one is wrong [AIIMS 2005]

(a) Lysosomes are double membraned vesicles budded off from golgi apparatus and contain digestive enzymes  
(b) Endoplasmic reticulum consists of a network of membranous tubules and helps in transport, synthesis and secretion  
(c) Leucoplast are bound by two membranes lack pigment but contain their own DNA and protein synthesizing machinery  
(d) Sphaerosomes are single membrane bound and are associated with synthesis and storage of lipids

7. Match List I and List II and select the correct answer using the code given below the list :

List I		List II	
a	Lysosome	1	Bacteria without cell walls
b	Mycoplasma	2	A virus that infects bacterial cells
c	Thylakoid	3	Flattened sacs in a chloroplast
d	Bacteriophage	4	A vesicle in which hydrolytic enzymes are stored

Code

[MP PMT 1993]

(a) a b c d (b) a b c d  
3 1 2 4 4 1 3 2  
(c) a b c d (d) a b c d  
2 3 4 1 1 4 2 3

8. Ribosome may also be called [RPMT 2005]  
(a) Microsome (b) Dictyosome  
(c) Ribonucleoprotein (d) Oxyosomes
9. Lysosomes are so called because these contain [MP PMT 1994]  
(a) Carboxylating enzymes (b) Respiratory enzymes  
(c) Oxidizing enzymes (d) Digestive enzymes
10. The organelles whose major function is storage of hydrolytic enzymes are [CPMT 1993, 98; MP PMT 1993, 2003, 09; CBSE PMT 1996; BVP 2000; HPMT 2005; RPMT 2005; NEET (Phase-II) 2016]  
Or  
Acid hydrolase is found in [MP PMT 2007; AFMC 2010]  
(a) Centrioles (b) Chromoplasts  
(c) Lysosomes (d) Chloroplasts
11. Which of the following subunit of ribosome is composed of 23S rRNA and a 5S rRNA +32 different proteins [Kerala PMT 2006]  
Or  
The largest subunit of prokaryotic ribosomes is [J & K CET 2008]  
(a) 50 S (b) 70 S  
(c) 30 S (d) 60 S  
(e) 40 S
12. The functional unit in the synthesis of protein is [MP PMT 1994; CBSE PMT 1999]  
(a) Peroxisome (b) Dictyosome  
(c) Lysosome (d) Polysome
13. Which one of the following structures is an organelle within an organelle [CBSE PMT (Malna) 2012]  
Or  
Which of the following cell organelle lacks DNA and bounding membrane [AFMC 2002; AIPMT 2015; AIPMT (Cancelled) 2015]  
(a) Ribosome (b) Peroxisome  
(c) ER (d) Mesosome
14. The cell organelle showing extensive polymorphism is [MHCET 2004; VITEEE 2008]  
(a) Dictyosomes (b) Chloroplasts  
(c) Lysosomes (d) Ribosomes
15. Lysosomes are known as suicidal bags because of [BHU 1999, 2012; RPMT 1999, 2006; CBSE PMT 2000; MP PMT 2003; HP PMT 2005; J & K CET 2010; PET (Pharmacy) 2013]  
Or  
Which one of the following is stored in lysosome [WB JEE 2016]  
(a) Catalytic enzymes (b) Hydrolytic enzymes  
(c) Parasitic on nucleus (d) Proteolytic enzymes
16. Ribosomes that occur exclusively in mitochondria is [DPMT 2004]  
(a) 70S (b) 55S  
(c) 30S (d) 50S
17. The "marker" enzyme of lysosome is [DPMT 2007]  
(a) Lysozyme (muramidase) (b) Acid protease  
(c) Acid phosphatase (d) Beta-galactosidase
18. Which of the following is present both in prokaryotic and eukaryotic cells [AFMC 2012; WB JEE 2016]  
(a) Mitochondria (b) Endoplasmic reticulum  
(c) Ribosomes (d) Nucleus
19. Peptide synthesis inside a cell takes place in [Odisha JEE 2009; CBSE PMT (Pre.) 2011]  
(a) Ribosomes (b) Chloroplast  
(c) Mitochondria (d) Chromoplast
20. Which of the following cell organelles is having single layered unit membrane [MP PMT 1995, 98; RPMT 1995; CBSE PMT 2001; CPMT 2005; J & K CET 2005; NEET (Phase-I) 2016]  
Or  
In active leaf cells, the double membrane is absent in [MP PMT 2013]  
(a) Centrosome (b) Lysosome  
(c) Mesosome (d) Nucleus
21. Who discovered "ribosomes" in animal cells [NCERT; BHU 2001]  
(a) Watson (b) Talvim  
(c) Cowdry (d) Palade
22. Ribosomes, similar to those of bacteria, are found in [CBSE PMT 2001]  
(a) Plant nuclei  
(b) Pancreatic mitochondria  
(c) Liver endoplasmic reticulum  
(d) Cardiac muscle cytoplasm
23. Which of the following statements is wrong for ribosomes [RPMT 1999]  
(a) Formed by two-sub units  
(b) Formed by ribo-protein  
(c) Formed in chain  
(d) Both sub-units are bounded by a membrane
24. Ribosomes of bacteria, mitochondria, prokaryotes (*Nostoc*) and chloroplast are of [MP PMT 1994, 99; MHCET 2001; J & K CET 2002; Kerala PMT 2004; Odisha JEE 2010; KCET 2011]  
(a) 50 S type (b) 80 S type  
(c) 70 S type (d) 30 S type
25. All are membrane bound cell organelles except [MP PMT 1997; RPMT 1999; DPMT 2003; BVP 2004; WB JEE 2010]  
Or  
Which of the following cell organelles lacks a unit membrane [MP PMT 1995, 98; RPMT 2002; J & K CET 2005; Kerala PMT 2010]  
(a) Mitochondria (b) Lysosomes  
(c) Sphaerosomes (d) Ribosomes
26. The 80S ribosomes are present in [MP PMT 1996; CPMT 1998]  
(a) Eucaryotic cells (b) Procaryotic cells  
(c) Bacterial cells (d) Cyanobacterial cells

27. Lysosomes have acidic environment inside their vesicles due to [BHU 2012]

(a) Production of carboxylate ions inside it  
(b) Production of phosphate ions inside it  
(c) High pH compared to outside  
(d) None of the above

28. Polyribosomes are aggregation of [CBSE PMT 2008]

(a) Ribosomes and rRNA  
(b) Only rRNA  
(c) Peroxisomes  
(d) Several ribosomes held together by a steering of mRNA

29. The site of protein synthesis in plants is the [CPMT 1994; MP PMT 1995, 2003; MDAT Bihar 1995; KCET 1999; CBSE PMT 1999; BVP 2001; BHU 2004; J & K CET 2005, 12; RPMT 2006]

Or

Which of the following organelle is called as "protein factory of the cell"

(a) Chloroplast (b) Ribosomes  
(c) Pyrenoids (d) Mitochondria

30. The cell organelle associated with intercellular digestion of macromolecules is [MP PMT 1999, 2002; Kerala PMT 2009]

Or

Which is concerned with autolysis [BVP 2004]

Or

One of the cell organelle is said to function as "trigger of cell division"

(a) Lysosome (b) Peroxisome  
(c) Polysome (d) Dictyosome  
(e) Glyoxysome

31. Most of the hydrolytic enzymes of lysosome function at [Odisha JEE 2012]

(a) Acidic pH (b) Alkaline pH  
(c) Neutral pH (d) Both (b) and (c)

32. Ribosomes are found in [MP PMT 2005]

(a) Cytoplasm (b) Nucleus  
(c) Cell wall (d) Golgibody

33. Heterophagosome is [Odisha JEE 2012]

(a) Formed by fusion of food containing phagosome with primary lysosome  
(b) A newly pinched out vesicle from Golgi apparatus which fuses with endosome to become fully functional  
(c) Formed by fusion of primary lysosome with degenerating intracellular organelles  
(d) A lysosome in which only indigestible food material is left

34. Which of the following is responsible for the origin of lysosome [MP PMT 2009]

(a) Chloroplast (b) Mitochondria  
(c) Golgi body (d) Ribosome

35. Ribosomes are made up of [MP PMT 1995, 98, 2006; BVP 2002; CPMT 2004]

(a) DNA and protein (b) DNA alone  
(c) RNA and protein (d) RNA and DNA

36. 70S type of ribosome shows two units whose sedimentation constants are [Odisha PMT 2002]

Or

Sub unit in prokaryotic ribosome is [DPMT 2007]

(a) 40 S and 30 S  
(b) 50 S and 20 S  
(c) 50 S and 30 S  
(d) 60 S and 20 S

37. Ribosome mainly has [DPMT 2004]

(a) DNA (b) RNA  
(c) Carbohydrate (d) None of these

38. Eukaryotic 80 S ribosome breaks into [MP PMT 1999, 2000, 03]

(a) 40 S and 40 S (b) 60 S and 40 S  
(c) 60 S and 50 S (d) 50 S and 30 S

39. Which of the following pairs is correct [CBSE PMT 1993]

(a) Svedberg unit — Biomembranes  
(b) Polyribosomes — RNA  
(c) Dictyosomes — Suicidal sacs  
(d) Cisternae — Mitochondria

40. What is true about ribosomes [CBSE PMT (Pre.) 2012]

(a) The prokaryotic ribosomes are 80 S, where "S" stands for sedimentation coefficient  
(b) These are composed of ribonucleic acid and proteins  
(c) These are found only in eukaryotic cells  
(d) These are self-splicing introns of some RNAs

### Sphaerosomes, Peroxisomes, Glyoxysomes and Vacuoles

1. The colour of rose petals is due to water soluble pigments present in the [MP PMT 1994]

(a) Cytoplasm (b) Nucleus  
(c) Intercellular spaces (d) Vacuoles

2. Match column I with column II and select the correct option

Column I		Column II	
A.	Sap vacuole	1.	Contain digestive enzyme
B.	Contractile vacuole	2.	Store metabolic gases
C.	Food vacuole	3.	Osmoregulation
D.	Air vacuole	4.	Store lipids
E.	Sphaerosomes	5.	Store and concentrate mineral salts & nutrients

[RPMT 1997; Kerala PMT 2006]

(a) A-5, B-3, C-1, D-2, E-4  
(b) A-2, B-3, C-4, D-5, E-1  
(c) A-5, B-2, C-3, D-1, E-4  
(d) A-5, B-3, C-2, D-4, E-1  
(e) A-4, B-1, C-3, D-5, E-2



3. Read the following statements and identify the correct options given
- A. Sap vacuoles-contain digestive enzymes with the help of which nutrients are digested options given
  - B. Contractile vacuoles – take part in osmoregulation and excretion
  - C. Food vacuoles – store and concentrate mineral salts as well as nutrients
  - D. Air vacuoles – store metabolic gases and help in buoyancy of cells [Kerala PMT 2008]
- (a) A and B are correct (b) A and C are correct  
(c) A and D are correct (d) B and D are correct  
(e) B and C are correct
4. Which is not true about sphaerosomes [Odisha JEE 2004]
- (a) Arise from ER.
  - (b) Related to fat
  - (c) Single membrane bound structure
  - (d) Involved in photorespiration
5. Peroxisomes are rich in [BHU 1999]
- (a) DNA (b) RNA
  - (c) Catalytic enzymes (d) Oxidative enzymes
6. Tonoplast is a [CPMT 1996, 98; AFMC 1999; BHU 1999, 2006; BVP 2000; MP PMT 2002, 09; Odisha JEE 2005, 09; HP PMT 2005; DUMET 2009; Kerala PMT 2009]
- (a) Covering layer of golgi complex
  - (b) Covering layer of vacuoles
  - (c) Covering layer of microbodies
  - (d) Non-living cytoplasmic content
7. Vacuole in a plant cell [CBSE PMT 2008]
- (a) Lacks membrane and contains air
  - (b) Lacks membrane and contains water and excretory substances
  - (c) Is membrane-bound and contains storage proteins and lipids
  - (d) Is membrane-bound and contains water and excretory substances
8. In which one of the following would you expect to find glyoxysomes [AIIMS 2005]
- (a) Endosperm of wheat (b) Endosperm of castor
  - (c) Palisade cells in leaf (d) Root hairs
9. Hyaloplasm of vacuole contains [MP PMT 2004]
- (a) Air (b) Water
  - (c) Water and minerals (d) Nothing
10. DNA remains absent in [MP PMT 2003, 09]
- (a) Chloroplast (b) Nucleus
  - (c) Peroxisomes (d) Chromosomes
11. What is degraded by Peroxisomes [RPMT 1997]
- (a) Carbon dioxide (b) Hydrogen peroxide
  - (c) Lithium oxide (d) Carbon monoxide
12. Which one of the following is not considered as a part of the endomembrane system [CBSE PMT (Mains) 2011]
- Or
- Which of the following has a single unit membrane [MP PMT 1999]
- (a) Vacuole (b) Lysosome
  - (c) Golgi complex (d) Peroxisome
13. Which one of the following is not a cell inclusion [Odisha JEE 2011]
- (a) Crystal (b) Vacuole
  - (c) Starch (d) Fat droplets
14. Which of the following is correct in plant cell [Odisha JEE 2008]
- (a) Bigger vacuole with rigid cell wall
  - (b) Centriole take part in cell division
  - (c) Centrosome are inactive in non-dividing cell
  - (d) Absence of cell membrane
15. In germinating seeds fatty acids are degraded exclusively in the [CBSE PMT 2008]
- (a) Peroxisomes (b) Mitochondria
  - (c) Proplastids (d) Glyoxysomes
16. Glyoxysomes occur in [Pune CET 1998]
- (a) Both plant and animal cells
  - (b) Plant cells only
  - (c) Animal cells only
  - (d) All types of cells
17. Some of the enzymes, which are associated in converting fats into carbohydrates, are present in [CBSE PMT 1999]
- Or
- Site of gluconeogenesis is [Odisha JEE 2008]
- (a) Liposomes (b) Golgi bodies
  - (c) Microsome (d) Glyoxysomes
18. The osmotic expansion of a cell kept in water is chiefly regulated by [AFMC 1999; CBSE PMT 2014]
- (a) Plastids (b) Ribosomes
  - (c) Mitochondria (d) Vacuoles
19. Which of the following parts of a cell is non-living [CPMT 1993]
- (a) Centriole (b) Vacuole
  - (c) Ribosomes (d) Mitochondria
20. The fluid part of cell called cell sap is the [AIIMS 1993; Manipal 2005]
- (a) Non-living contents of a cell
  - (b) Living contents of a cell
  - (c) Non-living contents of the vacuole of cell
  - (d) Living contents of the vacuole of cell
21. 'Peroxisome' is the microbody of a cell that helps in [WB JEE 2016]
- (a) Removal of electron and associated hydrogen
  - (b) Removal of proton
  - (c) Conversion of carbohydrate into fat
  - (d) Conversion of carbohydrate into protein

### Centrosomes / Centriole Cilia, Flagella and Microtubules

1. The plane of cell wall formation in a dividing cell is determined by [J & K CET 2012]

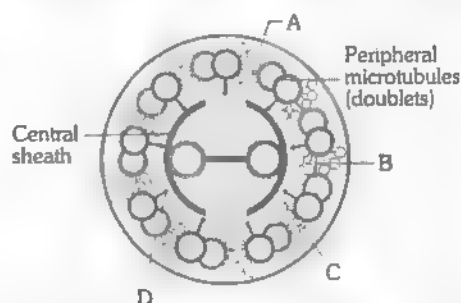
Or

The filaments associated with cilia and flagella are constituted by [AIIMS 1994; MP PMT 2000]

- (a) Golgi apparatus (b) Microfilaments
- (c) Microtubules (d) Endoplasmic reticulum

2. Centrioles and centrosomes are present in cells of  
[MP PMT 1997; HPMT 2005]  
(a) Bacteria (b) Cyanobacteria  
(c) Green plants (d) Animals
3. Function of centriole is [CPMT 1996; Kerala CET 2002; MP PMT 2003; J & K CET 2005]  
(a) Formation of spindle fibres  
(b) Formation of nucleolus  
(c) Initiation of cell division  
(d) Formation of cell plate
4. The function of centrosome is [CBSE PMT 2000]  
(a) Inhibition of cell division  
(b) Initiates cell division  
(c) To increase protein synthesis  
(d) None of these
5. Microtubules are absent in [AIIMS 2010]  
(a) Mitochondria (b) Flagella  
(c) Spindle fibres (d) Centriole
6. The main structure of centriole is  
(a) 9 + 3 fibrils  
(b) 9 + 2 fibrils  
(c) Nine triplets  
(d) 13 globular subunits
7. A plant cell usually differs from an animal cell in the absence of  
[MP PMT 1994, 2002; RPMT 2001; J & K CET 2002; DPMT 2003]  
Or  
Plant cells normally lack [AMU (Med.) 2012]  
Or  
Which of the following organelles is devoid of DNA yet is capable of duplication [MP PMT 2013]  
(a) Ribosomes (b) Centriole  
(c) Mitochondria (d) E.R.
8. The usual axonemal arrangement of microtubules is [AMU (Med.) 2012]  
(a) 6 pairs of doublets radially arranged at periphery with a pair of centrally located microtubules  
(b) 6 pairs of doublets radially arranged at periphery with a single centrally located microtubule  
(c) 9 pairs of doublets radially arranged at periphery with a pair of centrally located microtubules  
(d) 9 pairs of doublets radially arranged at periphery with a single centrally located microtubule
9. The solid linear cytoskeletal elements having a diameter of 6 nm and made up of a single type of monomer are known as [CBSE PMT 2014]  
(a) Intermediate filaments (b) Lamins  
(c) Microtubules (d) Microfilaments
10. Number of protofilaments in microtubule is [DPMT 2007]  
(a) 10 (b) 12  
(c) 5 (d) 13

11. See the section of cilia / flagella showing the different parts



- In which of the following options all the four blanks A, B, C and D are correctly identified [NCERT]  
(a) A – Plasma membrane, B – Interdoublet bridge, C – Hub, D – Arm  
(b) A – Plasma membrane, B – Interdoublet bridge, C – Hub, D – Radial spoke  
(c) A – Plasma membrane, B – Arm, C – Central microtubule, D – Radial spoke  
(d) A – Plasma membrane, B – Interdoublet bridge, C – Central microtubule, D – Radial spoke
12. Pattern of organisation of cilia and flagella is [Kashmir MEE 1995; AMU (Med.) 2009]  
(a) 9 + 0 (b) 9 + 1  
(c) 9 + 2 (d) 9 + 3
13. Flagella with single strand and composed of flagellin is found in [J & K CET 2002]  
(a) Prokaryotes (b) Eukaryotes  
(c) Both (a) and (b) (d) None of these
14. Basal bodies of cilia and flagella are derived from [DPMT 1993]  
(a) Plasma membrane (b) Genes  
(c) Centrioles (d) Lysosomes
15. The principal protein of cilia and flagella is  
(a) Tubulin (b) Albumin  
(c) Globulin (d) Gliadin
16. In flagellar membrane which enzyme catalyses ATP [DPMT 2007]  
(a) Cytoplasmic dynein (b) Asconic dynein  
(c) Kinesis (d) Myosin
17. Microtubules are the constituents of [NEET (Phase-I) 2016]  
(a) Cilia, Flagella and peroxisomes  
(b) Spindle fibres, Centrioles and Cilia  
(c) Centrioles, Spindle fibre and Chromatin  
(d) Centrosome, Nucleosome and Centrioles
18. Prokaryotic flagella possess [CBSE PMT 1995; BHU 2000]  
(a) Helically arranged protein molecule  
(b) Protein membrane enclosed fibre  
(c) Unit membrane enclosed fibre  
(d) Microtubular 9+2 membrane enclosed structure
19. Microtubule is involved in the [CBSE PMT 1998]  
(a) Cell division (b) DNA recognition  
(c) Muscle contraction (d) Membrane architecture

20. Tubulin protein occurs in [MP PMT 2004; Odisha JEE 2012]  
(a) Rough endoplasmic reticulum  
(b) Microtubules  
(c) Thylakoids  
(d) Digestive enzymes

21. An elaborate network of filamentous proteinaceous structures present in the cytoplasm which helps in the maintenance of cell shape is called

[CBSE PMT 2009; CBSE PMT (Mains) 2010]

- (a) Thylakoid (b) Endoplasmic Reticulum  
(c) Plasmalemma (d) Cytoskeleton

22. Term basal body is associated with the development of [CPMT 2002; RPMT 2005]

- (a) Cilia and flagella (b) Cell plate  
(c) Phragmoplast (d) Kinetochore

23. The main function of microtubules is [MP PMT 2006]

- (a) Protein synthesis  
(b) Movement of cilia and flagella  
(c) Formation of spindle fibres  
(d) Both (b) and (c)

24. Match List I and List II and select the correct answer using the code given below the lists

	List I	List II
1.	Microtubules	Structural components of cilia
2.	Centrioles	Store hydrolytic enzymes
3.	Peroxisomes	Store oil protein and starch in plants

Option [MP PMT 1993]

- (a) 1, 2 and 3 are correct  
(b) 1 and 2 are correct, 3 is false  
(c) 1 is correct, 2 and 3 are false  
(d) 1 and 3 are correct, 2 is false

25. Which of the following statements regarding cilia is not correct [CBSE PMT 2006]

- (a) Microtubules of cilia are composed of tubulin  
(b) Cilia contain an outer ring of nine double microtubules surrounding two single microtubules  
(c) The organised beating of cilia is controlled by fluxes of  $Ca^{2+}$  across the membrane  
(d) Cilia are hair-like cellular appendages

26. Consider the following statements

- (A) Plant cells have centrioles which are absent in almost all animal cells  
(B) Ribosomes are the site of protein synthesis  
(C) The middle lamella is a layer mainly of calcium carbonate which holds the different neighbouring cells together  
(D) In animal cell steroidal hormones are synthesized by smooth endoplasmic reticulum

Of the above statements [Kerala PMT 2010]

- (a) (A) and (B) only are correct  
(b) (C) and (D) only are correct  
(c) (B) and (D) only are correct  
(d) (A) and (D) only are correct  
(e) (B) and (C) only are correct

27. Microfilaments in eukaryotic cells are made up of [DUMET 2010]

- (a) Actin (b) Albumin  
(c) Globulin (d) Fibrin

28. The number of microtubules in a flagellum including those sharing three protofilaments with each other is [DUMET 2010]

- (a) 11 (b) 20  
(c) 22 (d) 10

### Nucleus and Chromosomes

1. Controlling centre of cell is [AFMC 1996]

Or

The "master mind" of the cell is

- (a) Nucleus (b) Nucleolus  
(c) Mitochondria (d) Ribosome

2. Four different types of chromosomes but of the same size are serialized as [MP PMT 1995]

- (a) Telocentric, metacentric, acrocentric, submetacentric  
(b) Metacentric, acrocentric, submetacentric, telocentric  
(c) Metacentric, submetacentric, acrocentric, telocentric  
(d) Metacentric, telocentric, acrocentric, submetacentric

3. Basic structure of chromatin is composed of [MP PMT 1999, 2001]

- (a) Non-histone proteins wrapped around DNA  
(b) Histone proteins wrapped around DNA  
(c) RNA wrapped around histones  
(d) DNA wrapped around histones

4. The function of nucleolus is the synthesis of [MP PMT 1994, 97; CPMT 2001; AIEEE (Pharmacy) 2009; CBSE PMT (Pre.) 2012]

- (a) DNA (b) m-RNA  
(c) r-RNA (d) t-RNA

5. Nuclear material without nuclear membrane is observed in [MP PMT 1994]

- (a) Bacteria and green algae  
(b) Cyanobacteria and red algae  
(c) Bacteria and cyanobacteria  
(d) Mycoplasmas and green algae

6. The nucleoplasm is continuous with the cytoplasm of a cell through [MP PMT 1994]

- (a) Centriole (b) Endoplasmic reticulum  
(c) Nuclear pores (d) Golgi apparatus

7. The term 'nucleolus' was coined by [AFMC 2001]

- (a) R. Brown (b) H. Hooks  
(c) Bowman (d) Hanstein

8. Karyolymph is a [Pb. PMT 2000]

- (a) Nuclear sap (b) SPM membrane  
(c) Nuclear pore (d) None of these

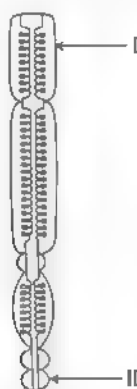
9. The nuclear spindle consists of [MP PMT 1995, 98]

- (a) One type of fibre (b) Two types of fibres  
(c) Three types of fibres (d) Four types of fibres

10. Karyology is the study of [JIPMER 1993; AFMC 2008]

- (a) Cell (b) Nucleus  
(c) Tissue (d) Genes

11. In the given diagram I and II indicate



[MHCET 2015]

- (a) Chromomere and chromonemata  
(b) Centromere and secondary constriction  
(c) Secondary constriction and satellite  
(d) Telomere and satellite
12. Spindle fibers attach on to [NEET (Phase-I) 2016]  
(a) Telomere of the chromosome  
(b) Kinetochore of the chromosome  
(c) Centromere of the chromosome  
(d) Kinetosome of the chromosome
13. Nucleoli are rich in [CBSE PMT 1993; BHU 2001; MP PMT 2003]  
(a) DNA and RNA (b) DNA, RNA and proteins  
(c) DNA (d) RNA
14. Histone proteins found in nuclei of eukaryotes are [CPMT 2000]  
(a) Acidic (b) Basic  
(c) Neutral (d) Amphoteric
15. The structure of nuclear membrane facilitates [CPMT 2002; RPMT 2005]  
(a) Synapsis of homologous chromosomes at meiosis  
(b) Nucleo-cytoplasmic exchange of materials  
(c) Anaphasic separation of daughter chromosomes  
(d) Organization of spindles
16. The nucleus has [CBSE PMT 1993]  
(a) One membrane with pores  
(b) Two membranes with pores  
(c) Two membranes with pores through which substances do not pass  
(d) Two membranes with pores through which macromolecules may pass
17. Spindle chromosomes have [CBSE PMT 2000]  
(a) Centriole (b) Kinetochore  
(c) Chromocentre (d) Chromomere

18. L-shaped chromosomes are called

[MP PMT 1999; BHU 2004]

Or

When the chromosome has a centromere nearer to one end of the chromosome resulting into one shorter and one longer arm, the chromosome is termed as [AMU (Med.) 2012]

- (a) Sex chromosome (b) Acrocentric  
(c) Telocentric (d) Sub-metacentric
19. The telomeres of eukaryotic chromosomes consist of short sequences of [CBSE PMT 2004; AIIMS 2007]  
(a) Adenine rich repeats (b) Guanine rich repeats  
(c) Thymine rich repeats (d) Cytosine rich repeats
20. Present in nucleolus is [MP PMT 2010]  
(a) Golgi complex (b) Lysosome  
(c) Mitochondria (d) Chromosome
21. A tetrad consists of [MP PMT 1993]  
(a) Four non-homologous chromatids  
(b) Four non-homologous chromosomes  
(c) Two sets of homologous chromosomes, each with two chromatids  
(d) Four homologous pairs of chromosomes
22. In nucleoplasm, a conspicuous body of spherical shape attached to a particular chromosome on a definite position is called [AIIMS 1998]  
(a) Plasmid (b) Karyolymph  
(c) Nucleolus (d) Nuclear reticulum
23. Identify the correct match between types of chromosomes and their descriptions
- |   | Chromosomes    |   | Position of centromere        |
|---|----------------|---|-------------------------------|
| A | Metacentric    | 1 | At the tip                    |
| B | Submetacentric | 2 | Almost near the tip           |
| C | Acrocentric    | 3 | At the middle                 |
| D | Telocentric    | 4 | Slightly away from the middle |
- Description [Kerala PMT 2004]  
(a) A-1, B-3, C-2, D-4 (b) A-4, B-3, C-2, D-1  
(c) A-1, B-2, C-3, D-4 (d) A-4, B-3, C-1, D-2  
(e) A-3, B-4, C-2, D-1
24. Who showed that the nuclear membrane has many pores or circular structures or annuli  
(a) Fawcett (b) Strasburger  
(c) Butcher (d) Callan and Tomlin
25. Nucleolemma is a part of  
(a) Nuclear membrane (b) Nuclear reticulum  
(c) Nucleolus (d) Nucleoplasm
26. Minimum haploid numbers of chromosomes in plant kingdom [RPMT 1999]  
(a) 3 (b) 2  
(c) 1 (d) 4

27. The given diagram shows a chromosome



Which of the following table refers correctly to the chromosome [NCERT]

	No. of centromere	No. of Kinetochores	No. of arms
(a)	1	2	2
(b)	2	2	4
(c)	1	2	4
(d)	2	1	4

28. In a cell that is not dividing, the chromosomes are visible as a tangle of fine threads called [MP PMT 1993]

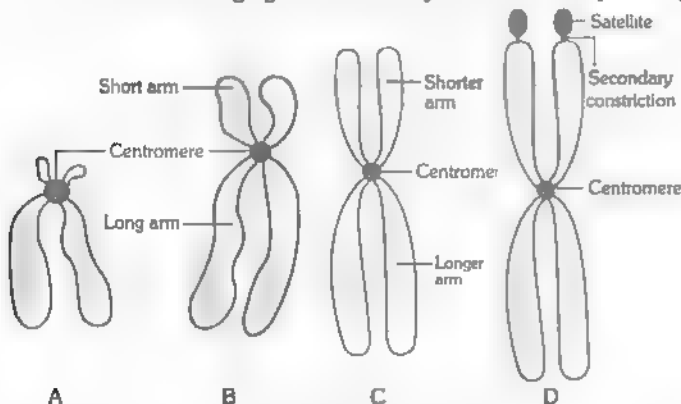
(a) Microtubules (b) Chromatin  
(c) Microfilaments (d) Nucleotin

29. The nucleus is separated from surrounding cytoplasm by a nuclear membrane, which is [MP PMT 1997; Pb. PMT 2004; BHU 2008]

(a) Single layered with pores  
(b) Single layered without pores  
(c) Double layered with pores  
(d) Double layered without pores

30. Nucleoproteins in a cell are synthesized in  
(a) Outside the nucleolus (b) Nucleoplasm  
(c) Nuclear membrane (d) Nucleolus

31. See the following figure and identify it [NCERT]



	A	B	C	D
(a)	Metacentric chr.	Submetacentric chr.	Acrocentric chr.	Telocentric chr.
(b)	Submetacentric chr.	Metacentric chr.	Telocentric chr.	Acrocentric chr.
(c)	Acrocentric chr.	Telocentric chr.	Metacentric chr.	Submetacentric chr.
(d)	Telocentric chr.	Acrocentric chr.	Submetacentric chr.	Metacentric chr.

32. The sex chromosomes of plants were first discovered in [CMC Vellore 1993]

(a) Algae (b) Fungi  
(c) Pteridophyta (d) Flowering plants

33. Which of the following are used to define the karyotype of a species

1. The number of chromosomes  
2. The chromosome length  
3. The positions of the centromeres

Code

[MP PMT 1993]

(a) 1, 2 and 3 are correct (b) Only 1 and 2 are correct  
(c) Only 2 and 3 are correct (d) Only 1 and 3 are correct

34. The part which does not take strain amongst the following is [CPMT 1993]

(a) Chromatid (b) Centromere  
(c) Chromatin (d) Chromomere

35. DNA is mainly found in [CBSE PMT 1999]

(a) Nucleus only (b) Nucleus and cytoplasm  
(c) Cytoplasm only (d) All of these

36. Which of the following is not contained in a eukaryotic nucleus [MHCET 2002]

(a) Nucleosome (b) Nucleolus  
(c) Chromatin (d) Circular DNA molecules

## NCERT Exemplar Questions

1. A common characteristic feature of plant sieve tube cells and most of mammalian erythrocytes is [NCERT]

(a) Absence of mitochondria (b) Presence of cell wall  
(c) Presence of haemoglobin (d) Absence of nucleus

2. Select one which is not true for ribosome [NCERT]

(a) Made of two sub units  
(b) Form polysome  
(c) May attach to mRNA  
(d) Have no role in protein synthesis

3. Which one of these is not a eukaryote [NCERT]

(a) Euglena (b) Anabena  
(c) Spirogyra (d) Agaricus

4. Which of the following dyes is best suited for staining chromosomes [NCERT]

(a) Basic Fuchsin (b) Safranin  
(c) Methylene blue (d) Carmine

5. Different cells have different sizes. Arrange the following cells in an ascending order of their size. Choose the correct option among the followings

i. Mycoplasma ii. Ostrich eggs  
iii. Human RBC iv. Bacteria

Options

[NCERT]

(a) i, iv, iii & ii (b) i, ii, iii & iv  
(c) ii, i, iii & iv (d) iii, ii, i & iv

6. Which of the following features is common to prokaryotes and many eukaryotes [NCERT]

(a) Chromosomes present  
(b) Cell wall present  
(c) Nuclear membrane present  
(d) Sub cellular organelles present

7. Which of the following statements is true for a secretory cell [NCERT]  
 (a) Golgi apparatus is absent  
 (b) Rough Endoplasmic Reticulum (RER) is easily observed in the cell  
 (c) Only Smooth Endoplasmic Reticulum (SER) is present  
 (d) Secretory granules are formed in nucleus
8. What is a tonoplast [NCERT]  
 (a) Outer membrane of mitochondria  
 (b) Inner membrane of chloroplast  
 (c) Membrane boundary of the vacuole of plant cells  
 (d) Cell membrane of a plant cell
9. Which of the following is not true of a eukaryotic cell [NCERT]  
 (a) It has 80S type of ribosome present in the mitochondria  
 (b) It has 80S type of ribosome present in the cytoplasm  
 (c) Mitochondria contain circular DNA  
 (d) Membrane bound organelles are present
10. Which of the following statements is not true for plasma membrane [NCERT]  
 (a) It is present in both plant and animal cell  
 (b) Lipid is present as a bilayer in it  
 (c) Proteins are present integrated as well as loosely associated with the lipid bilayer  
 (d) Carbohydrate is never found in it
11. Plastid differs from mitochondria on the basis of one of the following features. Mark the right answer [NCERT]  
 (a) Presence of two layers of membrane  
 (b) Presence of ribosome  
 (c) Presence of chlorophyll  
 (d) Presence of DNA
12. Which of the following is not a function of cytoskeleton in a cell [NCERT]  
 (a) Intracellular transport  
 (b) Maintenance of cell shape and structure  
 (c) Support of the organelle  
 (d) Cell motility
13. The stain used to visualise mitochondria is [NCERT]  
 (a) Fast green (b) Safranin  
 (c) Aceto carmine (d) Janus green



## Critical Thinking

### Objective Questions

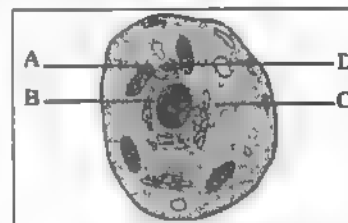
1. Match the following with correct combination

Column I		Column II	
A.	Endoplasmic reticulum	1.	Stack of cisternae
B.	Spherosome	2.	Store oils or fats
C.	Dictyosomes	3.	Synthesis and storage of lipids
D.	Peroxisome	4.	Photorespiration
E.	Elaaioplasts	5.	Detoxification of drugs

[Kerala PMT 2008]

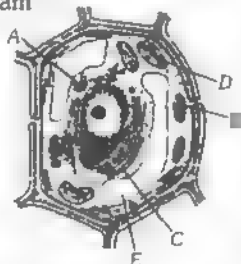
- (a) A-5, B-3, C-1, D-4, E-2  
 (b) A-5, B-3, C-2, D-4, E-1  
 (c) A-2, B-3, C-1, D-4, E-5  
 (d) A-3, B-3, C-1, D-5, E-2  
 (e) A-3, B-5, C-1, D-4, E-2

2. The RER in the cell synthesised a protein which would be later used in building the plasma membrane. But it is observed that the protein in the membrane is slightly different from the protein made in the RER. The protein was probably modified in another cell organelle. Identify that organelle in the given diagram [KCET 2009]



- (a) D (b) A  
 (c) B (d) C
3. Cells obtained from an organism were homogenised and centrifuged. A test indicated that the cells contained glycogen. If you were asked to find out as quickly as possible whether the cells were from a plant or an animal, you would [KCET 2006]  
 (a) Examine the centrifuge for the presence of extracts of chloroplasts  
 (b) Answer immediately that the cells were from a plant source  
 (c) Examine the centrifuge for the presence of extracts of centrioles  
 (d) Answer immediately that the cells were from an animal source
4. Cellulose, the most important constituent of plant cell wall is made up of [CBSE PMT 1998; AIIMS 2007]  
 (a) Branched chain of glucose molecules linked by  $\alpha$  1, 6 glycosidic bond at the site of branching  
 (b) Unbranched chain of glucose molecules linked by  $\alpha$  1, 4 glycosidic bond  
 (c) Branched chain of glucose molecules linked by  $\alpha$  1, 4 glycosidic bond in straight chain and  $\alpha$  1, 6 glycosidic bond at the site of branching  
 (d) Unbranched chain of glucose molecules linked by  $\alpha$  1, 4 glycosidic bond
5. Which of the following statements are false  
 A. Most cells are tiny and their volume ranges from 1 to 1000  $\text{nm}^3$ .  
 B. Some cells have the microvilli to increase the absorptive surface area.  
 C. All cells arise from pre-existing cells.  
 D. In plants, translocation of solutes is performed by xylem vessels and tracheids.  
 E. According to cell theory all cells arise from abiotic material. [Kerala PMT 2006]  
 (a) A, C and E are false (b) A, D and E are false  
 (c) B, C and D are false (d) C, D and E are false  
 (e) A, B and C are false
6. Which of the following has centrioles [MP PMT 1994]  
 (a) Chromosomes (b) Spindle fibres  
 (c) Centrosomes (d) Centromeres

7. The diagram of the ultrastructure of a plant cell is given below. Identify the functions of the organelles labelled A, B, C, D, E in the diagram [KCET 2010]



A	B	C	D	E
(a) Intracellular transport	Site of oxidative phosphorylation	Principle director of macromolecular traffic	Site of photophosphorylation	Storage of cell sap
(b) Principle director of macromolecular traffic	Site of oxidative phosphorylation	Intracellular transport	Site of photophosphorylation	Storage of cell sap
(c) Site of photophosphorylation	Storage of cell sap	Intracellular transport	Site of oxidative phosphorylation	Principle director of macromolecular traffic
(d) Storage of cell sap	Site of oxidative phosphorylation	Principle direction of macromolecular traffic	Site of photophosphorylation	Intracellular transport

8. Disulphide bonds which acts as atomic staples to reinforce the conformation of proteins are found in [AIEEE Pharmacy 2003]

- (a) Endoplasmic reticulum (b) Lysosome  
(c) Golgi apparatus (d) Cytosol

9. Match the columns and identify the correct option [AIPMT 2015]

Column - I	Column - II
(A) Thylakoids	(i) Disc-shaped sacs in golgi apparatus
(B) Cristae	(ii) Condensed structure of DNA
(C) Cisternae	(iii) Flat membranous sacs in stroma
(D) Chromatin	(iv) Infoldings in mitochondria

- (a) (iii) (iv) (i) (ii)  
(b) (iii) (i) (iv) (ii)  
(c) (iii) (iv) (ii) (i)  
(d) (iv) (iii) (i) (ii)

10. Consider the following statements

- A. In prokaryotic cells a special membranous structure formed by the extension of the plasma membrane into the cell is known as polysome  
B. The smooth endoplasmic reticulum is the major site for synthesis of glycoproteins  
C. RuBisCo is the most abundant protein in the whole of biosphere  
D. Mitochondria, chloroplasts and peroxisomes are not considered as part of endomembrane system

Of the above statements

[Kerala PMT 2012]

- (a) C and D alone are correct  
(b) A and B alone are correct  
(c) B and C alone are correct  
(d) A and D alone are correct  
(e) B and D alone are correct

11. Cellular organelles with membranes are [AIPMT 2015]

- (a) Chromosomes, ribosome and endoplasmic reticulum  
(b) Endoplasmic reticulum, ribosomes and nuclei  
(c) Lysosomes, Golgi apparatus and mitochondria  
(d) Nuclei, ribosomes and mitochondria

12. House-keeping proteins occur in [AMU (Med.) 2010]

- (a) Endoplasmic reticulum (b) Golgi complex  
(c) Cytoskeleton (d) All of the above

13. Consider the following statements and select the correct option

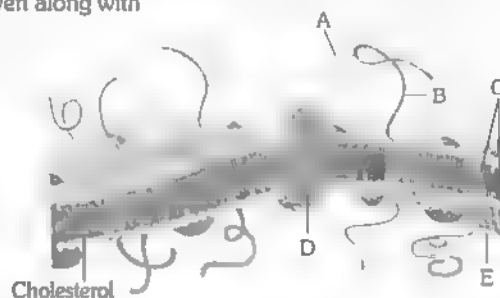
- A. The endomembrane system includes plasma membrane, ER, Golgi complex, lysosomes and vacuoles  
B. ER helps in the transport of substances, synthesis of proteins, lipoproteins and glycogen  
C. Ribosomes are involved in protein synthesis  
D. Mitochondria help in oxidative phosphorylation and generation of ATP [Kerala PMT 2011]

- (a) B, C and D are correct (b) A - alone is correct  
(c) B - alone is correct (d) C - alone is correct  
(e) D - alone is correct

14. Which of the following four cell structures is correctly matched with the accompanying description [AIIMS 2009]

- (a) Plasma membrane - Outer layer of cellulose or chitin, or absent  
(b) Mitochondria - Bacteria like elements with inner membrane forming sacs containing chlorophyll, found in plant cells and algae  
(c) Chloroplasts - Bacteria like elements with inner membrane highly folded  
(d) Golgi apparatus - Stacks of flattened vesicles

15. See the given diagram (cell membrane) and identify the components labelled A, B, C, D and E from the list (i) to (vii) given along with



#### Components

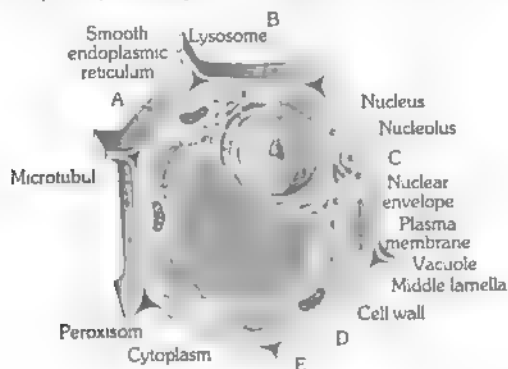
- (i) Sugar (ii) Protein  
(iii) Lipid bilayer (iv) Integral protein  
(v) Cytoplasm (vi) Cell wall  
(vii) External protein

The correct components are

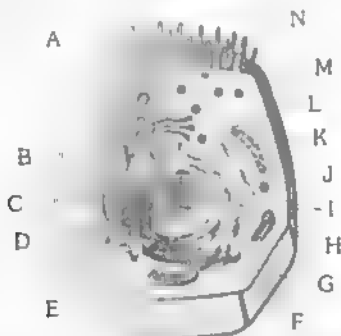
[NCERT]

- (a) A - (i), B - (ii), C - (iii), D - (vii), E - (v)  
(b) A - (i), B - (ii), C - (iii), D - (iv), E - (vi)  
(c) A - (ii), B - (i), C - (iii), D - (iv), E - (v)  
(d) A - (i), B - (ii), C - (iii), D - (iv), E - (v)

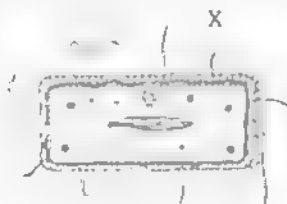
16. The given figure shows some of the missing structures in a plant cell (A - E). Identify the marked alphabets [NCERT]



- (a) A - Tight junction, B - Rough endoplasmic reticulum, C - Golgi apparatus, D - Mitochondrion, E - Ribosome  
 (b) A - Plasmodesmata, B - Smooth endoplasmic reticulum, C - Golgi apparatus, D - Mitochondrion, E - Ribosomes  
 (c) A - Desmosome, B - Rough endoplasmic reticulum, C - Golgi apparatus, D - Mitochondrion, E - Ribosomes  
 (d) A - Plasmodesmata, B - Rough endoplasmic reticulum, C - Golgi apparatus, D - Mitochondrion, E - Ribosomes
17. The given diagram shows important structures in an animal cell. Identify it



- (I) The structure replicates during mitosis and generates the spindle  
 (II) Major site for synthesis of lipid  
 (III) Power house of the cell  
 (IV) Store house of digestive enzyme  
 (V) Increases the surface area for the absorption of materials  
 (VI) Site of glycolysis  
 (VII) Site for active ribosomal RNA synthesis [NCERT]
- (a) I - M, II - A, III - H, IV - J, V - N, VI - F, VII - D  
 (b) I - L, II - B, III - H, IV - J, V - N, VI - F, VII - D  
 (c) I - L, II - G, III - H, IV - J, V - N, VI - F, VII - D  
 (d) I - L, II - G, III - H, IV - J, V - N, VI - F, VII - D
18. Some bacterial cells were fixed for microscopic observation. A structure X was observed on most occasions at the cell membrane



- In the above diagram, label X represents [NCERT]  
 (a) Mesosome (b) Ribosome  
 (c) Plasmids (d) Nucleoid

19. Match the following and select the correct answer

A.	Centriole	(i)	Infoldings in mitochondria
B.	Chlorophyll	(ii)	Thylakoids
C.	Cristae	(iii)	Nucleic acids
D.	Ribozymes	(iv)	Basal body cilia or flagella

[CBSE PMT 2014]

	A	B	C	D
(a)	(i)	(iii)	(ii)	(iv)
(b)	(iv)	(iii)	(i)	(ii)
(c)	(iv)	(ii)	(i)	(iii)
(d)	(i)	(ii)	(iv)	(iii)

20. Mitochondria and chloroplast are  
 (a) Semi-autonomous organelles  
 (b) Formed by division of pre-existing organelles and they contain DNA but lack protein synthesizing machinery  
 Which one of the following options is correct [NEET (Phase-I) 2016]

- (a) Both (a) and (b) are correct  
 (b) (b) is true but (a) is false  
 (c) (a) is true but (b) is false  
 (d) Both (a) and (b) are false

21. Cytoskeletal network of a cell is built by a process called [WB JEE 2016]  
 (a) Triphasic polymerization (b) Biphasic polymerization  
 (c) Trendmilling (d) Dynamic instability

## R Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

- (a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion  
 (b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion  
 (c) If the assertion is true but the reason is false  
 (d) If both the assertion and reason are false  
 (e) If the assertion is false but reason is true

1. Assertion : The number of mitochondria in a cell do not correspond to the function of the cell.  
 Reason : Mitochondria are common to both plant and animal cells. [KCET 2006]
2. Assertion : Mitochondria and chloroplasts are semiautonomous organelles.  
 Reason : They are formed by division of pre-existing organelles as well as contain DNA but lack protein synthesizing machinery [AIIMS 2005]
3. Assertion : A cell membrane shows fluid behaviour.  
 Reason : A membrane is a mosaic or composite of diverse lipids and proteins. [AIIMS 2003]



4. Assertion : Lysosomes help in photorespiration.  
Reason : Lysosome have basic enzyme. [AIIMS 1999]
5. Assertion :  $\text{Na}^+ - \text{K}^+$  ATPase is an important membrane associated enzyme.  
Reason : It helps in ion transfer across the membrane.
6. Assertion : The number of cells in a multicellular organism is inversely proportional to the size of body.  
Reason : All the cells in the biological world are of same size. [AIIMS 2002]
7. Assertion : It is important that the organisms should have cell.  
Reason : A cell keeps its chemical composition steady within its boundary. [AIIMS 2002]
8. Assertion : Leucoplasts give rise to other types of plastids.  
Reason : Chromoplasts do not get changed to other types of plastids.
9. Assertion : Cell wall is not found in animal cell.  
Reason : Animal cells are covered by cell membrane. [AIIMS 2001, 13]
10. Assertion : ER acts as a circulatory system.  
Reason : ER functions as cytoskeleton.
11. Assertion : Eukaryotic cells have more DNA than prokaryotic cells.  
Reason : Eukaryotes are genetically more complex than prokaryotes. [MP PMT 1993]
12. Assertion : Schleiden and Schwann were the first to observe the cells and to put forward cell theory.  
Reason : The cells are always living unit. [AIIMS 1994]
13. Assertion : Cell membrane is semipermeable.  
Reason : The constituent molecules can freely move in the membrane. [AIIMS 1994]
14. Assertion : Mitochondria is known as power house of cell.  
Reason : ATP production takes place here. [AIIMS 2000]

## Answers

### Tools and Technique

1	a	2	a	3	a	4	a	5	c
6	a	7	a	8	a	9	e	10	a
11	a	12	d	13	d	14	c	15	d
16	b	17	a	18	a	19	c	20	b
21	a	22	b	23	a	24	b	25	d
26	a	27	b	28	c	29	b	30	b
31	d	32	b	33	c	34	c	35	c

36 d 37 a

### Cell Introduction and Cell Theory

1	a	2	d	3	b	4	b	5	c
6	d	7	d	8	b	9	d	10	c
11	a	12	c	13	d	14	b	15	d
16	c	17	d	18	d	19	c	20	b
21	d	22	e	23	d	24	d	25	a
26	d	27	d						

### Cell wall

1	b	2	c	3	b	4	c	5	d
6	d	7	c	8	d	9	d	10	c
11	c	12	d	13	a	14	b	15	c
16	b								

### Plasma Membrane

1	c	2	d	3	a	4	b	5	a
6	d	7	d	8	d	9	d	10	c
11	d	12	c	13	b	14	a	15	b
16	b	17	b	18	c	19	d	20	d
21	c	22	c	23	c	24	b	25	d
26	b	27	b	28	a	29	c	30	b
31	c	32	d	33	c				

### Protoplasm and Cytoplasm

1	a	2	d	3	a	4	b	5	b
6	a	7	b	8	d	9	d	10	d
11	d	12	b	13	a				

### Mitochondria

1	a	2	a	3	d	4	a	5	b
6	c	7	c	8	b	9	d	10	d
11	c	12	b	13	a	14	d	15	c
16	d	17	b	18	a	19	b	20	b
21	b	22	d	23	b	24	c	25	a
26	b	27	d	28	b	29	b	30	c
31	c	32	b						

### Plastids

1	c	2	b	3	d	4	b	5	d
6	c	7	d	8	a	9	a	10	a
11	d	12	a	13	c	14	d	15	b
16	a	17	a	18	b	19	c	20	a

21	b	22	c	23	c	24	c	25	a
26	a	27	c	28	a	29	a	30	d
31	d	32	c	33	d				

**Endoplasmic reticulum and Golgi body**

1	d	2	a	3	a	4	c	5	b
6	c	7	b	8	c	9	a	10	b
11	c	12	d	13	a	14	d	15	c
16	b	17	b	18	a	19	c	20	a
21	b	22	b	23	c	24	b	25	a
26	c	27	a	28	b	29	a	30	c

**Lysosome and Ribosomes**

1	b	2	b	3	b	4	a	5	c
6	a	7	b	8	c	9	d	10	c
11	a	12	d	13	a	14	c	15	b
16	b	17	c	18	c	19	a	20	b
21	d	22	b	23	d	24	c	25	d
26	a	27	d	28	d	29	b	30	a
31	a	32	a	33	a	34	c	35	c
36	c	37	b	38	b	39	b	40	b

**Sphaerosomes, Peroxisomes, Glyoxysomes and Vacuoles**

1	d	2	a	3	d	4	d	5	d
6	b	7	d	8	b	9	c	10	c
11	b	12	d	13	b	14	a	15	d
16	b	17	d	18	d	19	b	20	c
21	a								

**Centrosomes / Centriole  
Cilia, Flagella and Microtubules**

1	c	2	d	3	a	4	d	5	a
6	c	7	b	8	c	9	d	10	d
11	d	12	c	13	a	14	c	15	a
16	b	17	b	18	a	19	a	20	b
21	d	22	a	23	d	24	c	25	c
26	c	27	a	28	b				

**Nucleus and Chromosomes**

1	a	2	c	3	b	4	c	5	c
6	c	7	c	8	a	9	c	10	b

11	d	12	b	13	b	14	b	15	b
16	d	17	b	18	d	19	b	20	d
21	c	22	c	23	e	24	d	25	a
26	b	27	c	28	b	29	c	30	a
31	d	32	d	33	a	34	b	35	a
36	d								

**NCERT Exemplar Questions**

1	a	2	d	3	b	4	d	5	a
6	b	7	b	8	c	9	a	10	d
11	c	12	a	13	d				

**Critical Thinking Questions**

1	a	2	a	3	d	4	d	5	b
6	c	7	b	8	a	9	a	10	a
11	c	12	d	13	a	14	d	15	d
16	d	17	b	18	a	19	c	20	c
21	d								

**Assertion and Reason**

1	a	2	c	3	a	4	d	5	a
6	d	7	a	8	b	9	a	10	b
11	a	12	d	13	b	14	a		

**Answers and Solutions****Tools and Technique**

- (a) Differentiation capacity of compound microscope depends upon numerical aperture of the objective lens system and its wavelength (3900-7600 Å). Depending upon the type of visible light used, the resolving power of a light microscope ranges from 0.2  $\mu\text{m}$  to 0.4  $\mu\text{m}$ .
- (a) Electron microscope is predominantly used for viewing of ultrastructure of cell and its organelles. Because it has great magnification and resolving power.
- (a) Electron microscope can magnify the objects upto 2,00,000 times (now possible upto 2,50,000 – 4,00,000) and direct of objects is possible on this microscope. Presence of ribosomes (size 23nm in diameter) is revealed with the help of electron microscope.
- (a) Agarose extracted from sea weeds finds use in gel electrophoresis.

28. (c) Electromagnetic lenses used in electron microscope having a coil of wire enclosed in soft iron casing.
30. (b) 1 Micrometer ( $\mu\text{m}$ ) =  $10^{-6}\text{m}$ ,  $10^{-4}\text{cm}$ ,  $10^{-3}\text{mm}$ ,  $1000\text{nm}$ .
32. (b) Phase contrast microscope is used to observe living cells and cell organs i.e., spindle fibres, pinocytosis, karyokinesis, cytokinesis etc.
33. (c) Autoradiography is a technique of studying the route of chemicals in chemical reactions taking place inside the cell and organisms with the help of radioactive isotopes i.e.,  $^{14}\text{C}$ ,  $^3\text{H}$ ,  $^{32}\text{P}$ .
36. (d) Differential centrifugation : It is a mechanical separation of individual subcellular component from homogenate in centrifuge at different low speeds. Large/heavy/denser particles settle down first at lower speeds while the lighter/smaller/less denser particles do so at higher speeds in centrifuge.
7. (d) According to fluid mosaic model, the arrangement of lipid molecules in plasma membrane is head parallel. It means head of both lipid layer towards the outside.
9. (d) Surface of plasma membrane has the ion carriers which participates in exchange of ions.
16. (b) Lipoprotein cell membrane is found in both but ribosomes are of different kinds
21. (c) Proline is a secondary amino acid which is not found in plasma membrane
27. (b) There are many different proteins embedded in the membrane. Except for flip flop movements rest occurs. Choice (a) is amply demonstrated when the travelling proteins aggregate at sites of endocytosis. Choice (c) type of proteins can be enzymes which are confined to certain domains (for e.g., present only on cell surface) choice (d) types are non-transmembrane proteins.
31. (c) According to Singer and Nicolson model, proteins are dispersed in layer of phospholipid.

### Cell Introduction and Cell theory

1. (a) M.J. Schleiden and T. Schwann (1838 – 39) proposed cell theory.
2. (d) Viruses are not applicable to cell theory. They are made up of proteins and one of nucleic acids i.e., DNA or RNA. So they lack protoplasm, the essential part of the cell.
3. (b) The prokaryotic cells do not have nuclear membrane while eukaryotic cell have well organised nuclear membrane.
4. (b) Because cell organelles are absent in prokaryotes.
5. (c) In present time three types of cells are known i.e., prokaryotic, mesokaryotic and eukaryotic.
8. (b) Virchow gave 'Omnis cellula a cellula' theory.
11. (a) In all living cells water forms 50-80% of total cell contents.
14. (b) Because the membrane which surrounds the vacuole is known as tonoplast.
17. (d) Cell organelles like mitochondria, golgi complex, E.R. and lysosomes etc. are present only in eukaryotes.
20. (b) Cell was discovered by Robert Hooke in 1665, when he observed tiny cavities bounded by definite walls in the sections of cork.
23. (d) Pleuro-pneumonia like organism (PPLO), *Mycoplasma gallisepticum* is having an average size of  $0.150\mu$ .

### Cell wall

1. (b) Through plasmodesmata, plasmoderm or a fine thread of protoplasm is passing.
10. (c) A polysaccharide is made up of many units of monosaccharides

### Plasma membrane

4. (b) Anthocyanin pigment cannot come outside due to impermeability of plasma membrane.
5. (a) Secondary wall situated near the plasma membrane. After the formation of primary wall.

### Protoplasm and Cytoplasm

3. (a) Ribosomes are the ribonucleoprotein particles of protoplasm.
5. (b) The pH of protoplasm is considered nearly as 7.
10. (d) Water is the basic component of the cytoplasm.
13. (a) The whole living material of cell is called protoplasm (According to Huxley, 1968).

### Mitochondria

1. (a) Kolliker (1880), observed mitochondria in striated muscle cell of insect.
7. (c) Oxysomes (Elementary particles or inner membranes sub-units or  $F_1$  particles); these are responsible for respiratory chain phosphorylation.
9. (d) Infolding of plasma membrane in bacteria are called mesosomes, which are analogous to mitochondria.
11. (c) Mitochondria without outer membrane is called as mitoplast
13. (a) Cristae are finger like process projecting inwards.
14. (d) Mitochondria are called power house or storage batteries or ATP mills as these are sites of ATP formation (Respiration) through electron transport and oxidative phosphorylation which is used in various metabolic activities/functions of the cell
16. (d) Mitochondria is responsible for the process of respiration which is a catabolic process. Mitochondria is a respiratory organelle where oxidation of stored food material takes place.
24. (c) Small DNA particles are present in mitochondria and chloroplast. They can duplicate and work as genetic material.
30. (c) Due to presence of 70s ribosome, RNA and ds circular DNA mitochondria is semiautonomous.

**Plastids**

1. (c) Plants are autotrophs and synthesize their food in the process of photosynthesis with the help of chloroplast (plastid).
2. (b) The green colour of plants is due to chlorophyll, which is found in chloroplast
3. (d) Chromoplasts develop from proplastids, leucoplasts and chloroplasts. Transformation from chloroplasts is observed during ripening of fruits (e.g., Tomato, Chilli) when they change their colour from green to reddish orange.
4. (b) Presence of cell wall and chlorophyll is characteristic feature of plants.
5. (d) Plastids are the characteristic feature of photosynthetic eukaryotes. Blue green algae and bacteria are prokaryotes and fungi are saprophytic eukaryotes.
8. (a) Thylakoids are bag like structure which stacked as coins one above the other and formed grana.
14. (d) Plastids are present in plant cells and absent in most of the animal cells.
16. (a) Thylakoids are structural and functional elements of chloroplast, which is made up of quantasome having 230 chlorophyll molecules.
20. (a) Guard cells are specialised chlorophyllous epidermal cells
25. (a) The amyloplasts appear like proplastids. They store starch for a longer period.
27. (c) Lycopene is red coloured carotenoid present in chromoplast of tomato.
32. (c) The thylakoids of chloroplast are arranged in as stacks of coins or stacks of discs.

**Endoplasmic reticulum and Golgi body**

3. (a) The margins of cisternae of golgi body are slightly curved, so each cisternae has convex *cis* or forming face toward the nucleus and ER, whereas concave *trans* or maturing face towards the plasma membrane. It is believed that nuclear membrane and SER the source of small vesicles that fuse with the *cis* form.
8. (c) Golgi complex performs glycosyl transferase activity for addition of glycans on lipids and proteins.
9. (a) Because E.R. possesses ribosomes on their membrane which are responsible for protein synthesis.
13. (a) Mechanical supports, enzyme circulation are function of both RER and SER while the protein is synthesized by RER and detoxification of drugs by SER
14. (d) Ribosomes are bounded on RER with the help of ribophorin.
17. (b) Endoplasmic reticulum gives support to the cell.
19. (c) RER has ribosome on which protein synthesis occurs.
22. (b) The formation/origin of new golgi body is always from endoplasmic reticulum, cisternae are similar in both.
23. (c) Fat synthesis is the main function of smooth endoplasmic reticulum.

24. (b) Smooth endoplasmic reticulum is the part of endoplasmic reticulum on which ribosomes are not present which takes part in lipid synthesis, fat synthesis, glycosylation of carbohydrates, steroid synthesis and detoxification. Whereas rough endoplasmic reticulum is the site of protein synthesis.
27. (a) Golgi and ER are often found associated to nuclear membrane.
30. (c) Golgi apparatus; because it secretes many types of metabolic enzymes.

**Lysosome and Ribosomes**

2. (b) Because lysosome is polymorphic (primary, secondary, tertiary, autophagic) and polyfunctional cell organelle.
5. (c) Cell wall die due to the release of enzyme of lysosome (autolysis).
13. (a) Ribosome is present in some cell organelles like mitochondria. Ribosomes are membraneless organelles which are made up of two sub-units and mRNA.
14. (c) Lysosomes exist as primary, secondary and tertiary lysosomes
15. (b) Because it present hydrolytic enzyme, they can digest cell organelles and their parts.
16. (b) 5S ribosomes are found in mammalian mitochondria.
19. (a) Ribosomes are site of peptide bond formation.
21. (d) Ribosomes are also called palade particles.
22. (b) Bacterial ribosomes is 70 S type which resembles with mitochondrial ribosomes.
23. (d) Ribosomes are membraneless or without membranous structure.
25. (d) Ribosomes are solid particles of protein and not made up of any membrane.
29. (b) Ribosomes are called site of protein synthesis because two sub-units of ribosomes are attached with the thread of mRNA. This mRNA contains anticodes for protein synthesis.
30. (a) Because lysosome contains digestive enzymes capable of lysis, thus it is a lytic body or suicidal bag.
35. (c) Ribosome is a combination of rRNA and protein.

**Sphaerosomes, Peroxisomes, Glyoxysomes and Vacuoles**

5. (d) Peroxisomes contain glycolic acid oxidase, which oxidises glycolic acid (a product of photosynthesis) to glyoxylic acid.
8. (b) Glyoxysomes are enzymes which play a critical role in lipid metabolism in seedlings. Hence they are supposed to be present in endosperm of castor as endosperm of wheat will possess starch.
10. (c) DNA not found in peroxisomes, ribosomes, ER, golgi body etc.

**Centrosomes / Centriole  
Cilia, Flagella and Microtubules**

3. (a) During cell division spindle fibres attached on centriole.
9. (d) Microfilaments are ultramicroscopic long, narrow cylindrical solid rods or protein filaments (actin protein) of approx 8 nm in dm.

10. (d) T.S. of microtubules shows array of 13 rows of subunit i.e., protofilament having a diameter of 5 – 7 nm.
13. (a) The single stranded flagella occurs in prokaryotes e.g., Bacteria etc. They contain only single stranded and not contain 9 + 2 system.
16. (b) The arms of microtubules contain a protein asconic dyenin. It is an ATPase enzyme which catalyzes hydrolysis of ATP to ADP, and transfers the released energy to ciliary/flagellar work.
21. (d) Cytoskeleton-Microtubule, Microfilament and Intermediate filaments.
23. (d) Microtubules play a role in formation and contraction of the spindle during chromosome movement as well as in ciliary and flagellar motion.
3. (a) With the help of freeze-fracture techniques in electron microscopy, the fluid mosaic model was put forward in 1970 by S.J. Singer and G.L. Nicolson. According to this model plasma membrane is composed of phospholipids, extrinsic proteins (integral proteins). Selective permeability of plasma membrane can be explained with this model.
4. (d) Lysosomes have hydrolytic enzymes. These have no role in photorespiration.
5. (a) Of all the membrane associated enzymes,  $\text{Na}^+,\text{-K}^+$  ATPase is one of the most important because of its role in ion transfer across the plasma membrane. This enzyme is dependent on the presence of lipids and is inactivated when all lipids are extracted.
6. (d) Number of cells in a multicellular organism are directly proportional to the size of the body. On the other hand, it is a fact that cell vary greatly in their size. Mycoplasma cells are the smallest, ranging from 0.1 to  $0.3\mu\text{m}$ , whereas human cells, generally range from 20 to  $30\mu\text{m}$ . Nerve cells are the longest.
7. (a) Metabolic reactions of a living organism can occur only in a delicately balanced environment in the non-living organisms. The cells are the life supporting chambers which have such a special environment. A living cell keeps its chemical composition steady within its boundary.
8. (b) Leucoplasts can change to other types of plastids, but chromoplasts can not. Chromoplasts are formed either from leucoplasts or chloroplasts.
9. (a) Cell wall is characteristic feature of plant cells. Cell wall absent in animals. Animals cells covered by cell membrane.
10. (b) ER functions as cytoskeleton or intracellular and ultrastructural skeletal framework by providing mechanical support to colloidal cytoplasmic matrix. The ER may act as a circulatory system for intracellular circulation of various substances. Membrane flow may also be an important mechanism for carrying particles, molecules and ions into and out of the cells.
11. (a) Eukaryotic cells have more DNA than prokaryotic cells because in eukaryotic cells complex chromosomes composed of DNA and histone proteins. But in prokaryotic cells histone protein is absent.
12. (d) They are credited with cell theory but the cells are not always the living unit. Cell die and still remain functional such as horny cells in animal and xylem vessels in plants.
13. (b) Cell membrane is semi permeable as it allows continuous flow of selected materials across it as required from time to time. On the other hand, constituent molecules of cell membrane are free to move inside membrane.
14. (a) In mitochondria ATP production takes place. Therefore, mitochondria is called Power house.

### Nucleus and Chromosomes

7. (c) Nucleolus was discovered by Fontana. The term nucleolus was given by Bowman.
8. (a) Colloidal sap inside the nucleus is known as karyolymph or nucleoplasm.
15. (b) Holes in the centre of the nuclear pore provide the main channel through which water soluble molecules shuttle between the nucleus and cytoplasm. This channel also contains a protein called nucleoplasmin which facilitates nucleo-cytoplasm traffic through the pore.
17. (b) Chromosomes which adjoins with spindle fibres designated as spindle chromosomes. The position at which the spindle fibre is get attached, known as centromere or kinetochore.
19. (b) Eukaryotic telomeric DNA has been shown to consist of simple randomly repeated sequences characterized by clusters of G-residues in one strand and C-residues in the other. Another feature is a 3 overhang (12-16 nucleotides in length) of the G-rich strand.

### Critical Thinking Questions

19. (c) Ribozyme is catalytic RNA.

### Assertion and Reason

1. (e) Several work of cell carried out by mitochondria i.e., ATP synthesis, aerobic respiration, maternal inheritance etc.
2. (c) Mitochondria and chloroplasts both are double membrane organelles. They are semi autonomous as both their structure and functions are partially controlled by nucleus of the cell and partially themselves. Both possess their own DNA and arises from pre-existing cells. Synthesis of many amino acids occurs in mitochondria. The first formed amino acids are glutamic acid and aspartic acid.  
Also plastid manufactures some of its own proteins, enzymes and other chemicals because of the presence of 70s ribosomes which can help translate the coded information contained in mRNAs transcribed over chloroplast DNA.  
DNA replication is the process of forming carbon copy of DNA. Whereas transcription is the formation of RNA over DNA template.
11. (a) Eukaryotic cells have more DNA than prokaryotic cells because in eukaryotic cells complex chromosomes composed of DNA and histone proteins. But in prokaryotic cells histone protein is absent.
12. (d) They are credited with cell theory but the cells are not always the living unit. Cell die and still remain functional such as horny cells in animal and xylem vessels in plants.
13. (b) Cell membrane is semi permeable as it allows continuous flow of selected materials across it as required from time to time. On the other hand, constituent molecules of cell membrane are free to move inside membrane.
14. (a) In mitochondria ATP production takes place. Therefore, mitochondria is called Power house.

## Cell : The Unit of Life

## ET Self Evaluation Test

1. The term lipochondria was suggested for [MP PMT 2011]
  - (a) Mitochondria (b) E. R.
  - (c) Golgi complex (d) All of these
2. Nucleoid is [MP PMT 2001]
  - (a) A single inactive nucleus having double stranded DNA and proteins
  - (b) A group of chromosomes associated with proteins
  - (c) A nucleus without nuclear membrane and nucleolus or genetic material of prokaryotes
  - (d) A chromosome associated with proteins
3. Green potatoes are toxic due to [MP PMT 2009]
  - (a) Phytoalexins (b) Solanin
  - (c) Triazine (d) Hormones
4. Desmosomes are [AFMC 2009]
  - (a) Connecting bodies between cells
  - (b) Fat storage cells
  - (c) Pigment bodies
  - (d) None of these
5. What is lacking in an animal cell [MP PMT 2011]
  - (a) Plasmodesmata (b) 80s ribosomes
  - (c) Centriole (d) All of these
6. Importance of mitochondria in respiration was first discovered by [RPMT 1999]
  - (a) S. Madani (b) Meves
  - (c) Michaelis (d) Barbergan
7. Electron transport system in mitochondria is located in [MP PMT 1997; MHCET 2001]
  - (a) Outer membrane (b) Inter-cristae space
  - (c) Inner membrane (d) Inner membrane space
8. What is the proportion of lipids in chloroplast [MP PMT 2011]
  - (a) 5-10% (b) 40-50%
  - (c) 1-2% (d) 20-30%
9. Match the following
 

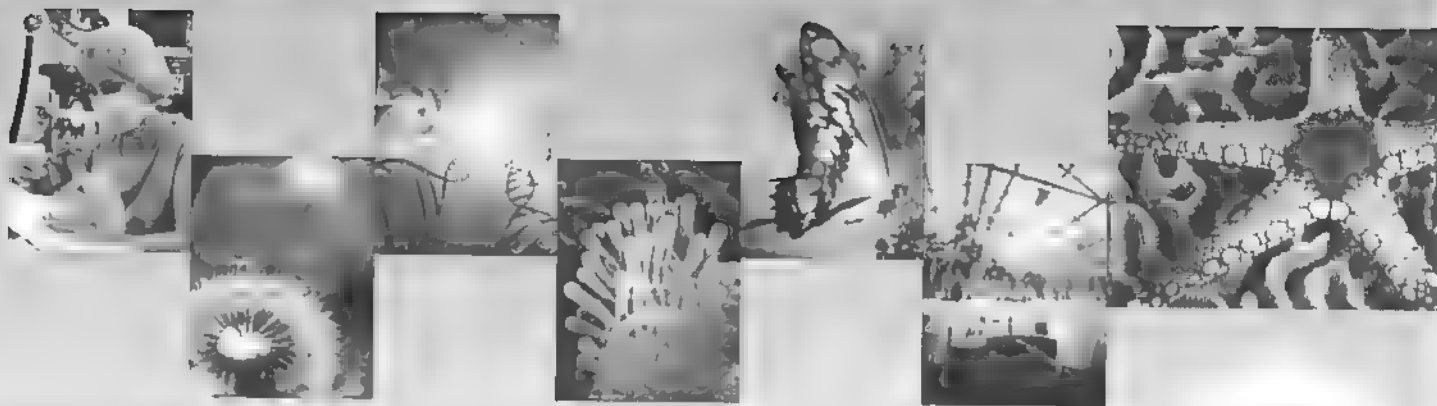
A. Bacteria B. Sphaerosomes C. Chloroplasts D. Karyotype	1. Synthesis and storage of lipids 2. Idiogram 3. Glycocalyx 4. Thylakoids
---	---

 [Kerala PMT 2006]
  - (a) A - 3, B - 2, C - 4, D - 1
  - (b) A - 3, B - 1, C - 2, D - 4
  - (c) A - 4, B - 3, C - 2, D - 1
  - (d) A - 1, B - 2, C - 3, D - 4
  - (e) A - 3, B - 1, C - 4, D - 2
10. Phragmoplast is [JIPMER 2002]
  - (a) Cell plate formed by endoplasmic reticulum and products of dictyosome during cytokinesis
  - (b) Cell membrane formed by endoplasmic reticulum, golgi bodies and secretory vesicles during cytokinesis
  - (c) Plastid capable of fragmentation
  - (d) Plastid capable of duplication
11. One of the most common enzyme found in peroxisome is [Odisha PMT 2002]
  - (a) Hydrolase (b) Catalase
  - (c) Dehydrogenase (d) Reductase

## Answers

1	c	2	c	3	a	4	a	5	a
6	c	7	c	8	d	9	e	10	a
11	b								

\* \* \*



## Chapter 3.2

# Biomolecules

### Micromolecules

These are molecules of low molecular weight and have higher solubility. These include minerals, water, amino acid, sugars and nucleotides. All molecules or chemicals functional in life activity are called *biomolecules*.

(1) **Elements** : On the basis of presence and requirement in plants and animals, they are grouped into major (Ca, P, Na, Mg, S, K, N) and minor (Fe, Cu, Co, Mn, Mo, Zn, I) bioelements.

On the basis of function, they may be of following types :

(i) **Framework elements** : Carbon, oxygen and hydrogen.

(ii) **Protoplasmic elements** : Protein, nucleic acid, lipids, chlorophyll, enzymes, etc.

(iii) **Balancing elements** : Ca, Mg and K.

(2) **Biological compounds**

(i) **Inorganic compounds** : Water 80%, inorganic salts 1-3%.

(ii) **Organic compounds** : Carbohydrates (1.0%), Lipids (3.5%), Proteins (12.0%) Nucleotides (2.0%), Other compounds (0.5).

(3) **Cellular pool** : Aggregated and interlinked various kinds of biomolecules in a living system. So cell is called cellular pool. It includes over 5000 chemicals. Inorganic chemicals are present mostly in aqueous phase while organic in both, aqueous and non-aqueous. Cellular pool comprises of both crystalline and colloidal particles. Hence called as crystal colloids.

(4) **Water** : Liquid of life, major constituent of cell (about 60-90%) and exists in intracellular, intercellular and in vacuoles. In cells it occurs in free state or bound state (KOH, CaOH etc.).

**Properties of water** : It is colourless, transparent, tasteless and odourless, neutral (pH-7) liquid. It is universal solvent, as it can dissolve both polar and non-polar solutes. High boiling point due to hydrogen bonding. Shows high degree of cohesion and adhesion. It can undergo three states of matter i.e., solid  $\rightarrow$  liquid  $\rightarrow$  gas. It is dense and heaviest at 4°C and solid below it.

(5) **Carbohydrates** : e.g., sugars, glycogen (animal starch), plant starch and cellulose.

**Source of carbohydrate** : Mainly photosynthesis. It exists only in 1% but constitutes 80% of the dry weight of plants.

**Composition** : It consists of carbon, hydrogen and oxygen in the ratio  $C_nH_{2n}O_n$ . It is also called saccharide and sugars are their basic components. Classification of carbohydrates are :

(i) **Monosaccharides** : These are single sugar units which can not be hydrolysed further into smaller carbohydrates. General formula is  $C_nH_{2n}O_n$ , e.g., Trioses-3C, (Glyceraldehyde, dihydroxyacetone etc.), tetroses-4C, pentoses-5C, hexoses-6C etc.

### Important Hexoses

**Glucose** :  $C_6H_{12}O_6$ . Grape sugar is dextrose. Grape is sour due to presence of tartaric acid. Fructose is called fruit sugar (sweetest among natural sugars) and glucose is called "sugar of body" (blood sugar). Normal level of blood glucose is 80-120mg/100ml. If it exceeds then condition is called "glucosuria".

**Fructose** : Occurs naturally in fruit juices and honey. Hydrolysis of cane sugar in body also yields fructose. The sweetest carbohydrate is fructose, which is also called fruit sugar because of its common occurrence in fruits (except grapes). It is also called levulose (because of its laevorotatory nature, i.e., rotates the plane of polarized light towards left). It has a sweetening index of 170 (whereas the sweetening index of glucose is 70).

**Galactose** : It is called as brain sugar. It's an important constituent of glycolipids and glycoproteins.

### Properties of monosaccharide

☐ Monosaccharides are colourless, sweet tasting, solids and show oxidation, esterification and fermentation.

☐ Due to asymmetric carbon, they exist in different isomeric forms. They can rotate polarized light hence they are dextrorotatory and laevorotatory.

☐ D-glucose after reduction gives rise to a mixture of polyhydroxy alcohol, sorbitol or mannitol.

**Functions of monosaccharides**

□ Glucose is the ultimate source of ATP in the cell respiration

□ Polymerisation of these molecules forms macromolecules.

□ Ribose and deoxyribose are constituent of nucleic acids and nucleotides.

□ Sugars have free aldehyde or ketone group which can reduce  $\text{Cu}^{++}$  to  $\text{Cu}^+$  and are called reducing sugars. Benedict's or Fehling's test are used to confirm the presence of reducing sugars.

(ii) **Oligosaccharides** : Formed due to condensation of 2-10 monosaccharide units, the Oxygen bridge is known as "glycoside linkage" and water molecule is eliminated. The bond may be  $\alpha$  and  $\beta$ .

(a) **Disaccharides** : Composed of two molecules of same or different monosaccharide units. Also called "double sugars". Molecular formula is  $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ .

**Maltose** : Also called "malt sugar" stored in germinating seeds of barley, oat, etc. It is formed by enzymatic (enzyme amylase) action on starch. It is a double sugar (disaccharide) made up of two molecules on each of  $\alpha$ -D glucose and  $\beta$ -D glucose joined by  $\alpha$  1  $\rightarrow$  4 glycosidic bond. It is a reducing sugar.

**Sucrose** : "Cane sugar" or "table-sugar". Obtained from sugarcane and beet root and on hydrolysis splits into glucose and fructose. It is a non reducing sugar.

**Lactose** : Milk sugar or 5% in mammalian milk. On hydrolysis yields glucose and galactose. *Streptococcus lacti* converts lactose into lactic acid and causes souring of milk.

(b) **Trisaccharides** : Composed of three molecules of sugars. Molecular formula is  $\text{C}_{18}\text{H}_{32}\text{O}_{16}$ .

**Raffinose** : Found in sugar beet, cotton and in some fungi. It is made up of glucose, fructose and galactose.

**Gentianose** : Found in rhizomes of gentian species, made up of glucose and fructose.

(c) **Tetrasaccharides** : Composed of four molecules of same or different sugars. Stachyose is found in *Stachys tubefera*. It is made up of two unit of galactose, one unit of glucose and one unit of fructose

(d) **Polysaccharides** : General formula is  $(\text{C}_6\text{H}_{10}\text{O}_5)_n$  formed by condensation of several molecules (300-1000) of monosaccharides, (Described under "Macromolecules").

(6) **Lipids** : Term lipid was coined by Bloor (1943). These are esters of fatty acids and alcohol. They are hydrophobic insoluble in water but soluble in benzene, ether and chloroform. Lipids are classified into three groups :

(i) **Simple lipids** : These are the esters of fatty acids and glycerol. Again they are typed as :

(a) **Fats and Oils** : (Natural lipids or true fats). These are triglycerides of fatty acid and glycerol. Fats which are liquid at room temperature are called oils.

(b) **Fatty acids** : Obtained by hydrolysis of fats. Formic acid is simplest fatty acid ( $\text{HCOOH}$ ). These are of 2 types :

□ **Saturated fatty acids** : The fatty acids which do not have double bond in between carbon atoms. e.g., butyric acid, palmitic acid, hexanoic acid, etc. They have high melting points and solid at room temperature.

□ **Unsaturated fatty acids** : The fatty acids which have double bonds (D.B.) in carbon atoms. e.g., oleic acid (1 D.B.), linolic acid (2 D.B.), linolenic acid (3 D.B.), arachidonic acid (4 D.B.) one D.B. containing fatty acid is called MUFA, and with more than one D.B. fatty acid is called PUFA. They have lower melting points mostly found in plant fats and liquid at room temperature.

Linoleic acid, linolenic acid, arachidonic acid are essential fatty acid (Evans and Burr 1928). Deficiency of essential fatty acid causes follicular hyper keratosis disease.

(c) **Waxes** : These are simple lipids composed of one molecule of long chain fatty acid and long chain monohydric alcohol. Waxes have high melting point, insoluble in water. They reduce rate of transpiration by making plant tissue water proof. Wax present in blood called cholesterol.

Bees wax is a common example of wax. It is a combination of palmitic acid and mericyl alcohol ( $\text{C}_{30}\text{H}_{61}\text{OH}$ ). Candil contains paraffin wax and stearic acid.

(ii) **Compound lipids** : They contain some additional element. Group with fatty acid and alcohol they may be of following types :

(a) **Phospholipids** : It is amphipathic molecule. These contain phosphoric acid. It helps in transport, metabolism, blood clotting and permeability of cell membrane. e.g., Lecithin, cephalin (Soyabean oil).

(b) **Glycolipids** : These contain nitrogen and carbohydrate beside fatty acids. Generally found in white matter of nervous system. e.g., sesocine frenocin.

(c) **Chromolipids** : It includes pigmented lipids e.g., carotene.

(d) **Aminolipids / Sulpholipids** : It contains sulphur and amino acids with fatty acid and glycerol. Cutin and suberin are also compound lipids.

(iii) **Derived lipids** : These are obtained by hydrolysis of simple and compound lipids. Derived lipids include following components :

(a) **Sterols** : Lipids without straight chains are called sterols. They are composed of fused hydrocarbon rings and a long hydrocarbon side chain. Best known sterol is cholesterol.

(b) **Digitalin** : It is prepared from leaves of Foxglove (*Digitalis lantana*) is a heart stimulant.

(c) **Ergosterol** : Present in food, found in ergot and yeast.

(d) **Coprosterol** : It is found in faeces. It is formed as a result of the reduction by bacteria in intestine from the double bond of cholesterol between  $\text{C}_5$  and  $\text{C}_6$ .

(e) **Terpenes** : It is essential oil and present mostly in oils of camphor, eucalyptus, lemon and mint. Phytol is a terpenoid alcohol present in Vitamin A, K, E and in pigments like chlorophyll carotenoid.



### Functions of lipids

- ❑ Oxidation of lipids yields comparatively more energy in the cell than protein and carbohydrates.
- ❑ The oil seeds such as groundnut, mustard, coconut store fats to provide nourishment to embryo during germination.
- ❑ They function as structural constituent i.e., all the membrane system of the cell are made up of lipoproteins.
- ❑ Amphipathic lipids are emulsifier.
- ❑ It works as heat insulator and Used in synthesis of hormones.
- ❑ Fats provide solubility to vitamins A, D, E, and K.

(7) **Amino acids** : Amino acids are basic units of protein and made up of C, H, O, N and sometimes S. Amino acids are organic acids with a carboxyl group ( $-\text{COOH}$ ) and one amino group ( $-\text{NH}_2$ ) on the  $\alpha$ -carbon atom. Carboxyl group attributes acidic properties and amino group gives basic ones. In solution, they serve as buffers and help to maintain pH. General formula is  $\text{R}-\text{CHNH}_2\text{COOH}$ . They are 20 in number specified in genetic code and universal in viruses, prokaryotes and eukaryotes. Which take part in protein synthesis.

Amino acids are amphoteric or bipolar ions or Zwitter ions. Amino acids link with each other by peptide bond and long chains are called polypeptide chains. Total known amino acid are more than 200 out of these only 20 amino acid takes part in protein synthesis called protein amino acid.

### Classification

#### (i) Based on R-group of amino acids

**Simple amino acids** : These have no functional group in the side chain. e.g., glycine, alanine, leucine, valine etc. Glycine is a simplest amino acid.

**Hydroxy amino acids** : They have alcohol group in side chain. e.g., threonine, serine, etc.

**Sulphur containing amino acids** : They have sulphur atom in side chain. e.g., methionine, cysteine.

**Basic amino acids** : They have basic group ( $-\text{NH}_2$ ) in side chain. e.g., lysine, arginine.

**Acidic amino acids** : They have carboxyl group in side chain. e.g., aspartic acid, glutamic acid.

**Acid amide amino acids** : These are the derivatives of acidic amino acids. In this group, one of the carboxyl group has been converted to amide ( $-\text{CONH}_2$ ). e.g., asparagine, glutamine.

**Heterocyclic amino acids** : These are the amino acids in which the side chain includes a ring involving atleast one atom other than carbon. e.g., tryptophan, histidine.

**Aromatic amino acids** : They have aromatic group (benzene ring) in the side chain. e.g., phenylalanine, tyrosine, etc.

(ii) **On the basis of requirements** : On the basis of the synthesis amino acids in body and their requirement, they are categorized as

**Essential amino acids** : These are not synthesized in body hence to be provided in diet e.g., valine, leucine, isoleucine, threonine, lysine, tryptophan, phenylalanine, methionine etc.

**Semi-essential amino acids** : Synthesized partially in the body but not at the rate to meet the requirement of individual. e.g., arginine and histidine.

**Non-essential amino acids** : These amino acids are derived from carbon skeleton of lipids and carbohydrate metabolism. In humans there are 12 non-essential amino acids e.g., alanine, aspartic acid, cysteine, glutamic acid etc. Proline and hydroxyproline have,  $\text{NH}$  (imino group) instead of  $\text{NH}_2$  hence are called imino acids.

(8) **Nucleotides** : Structurally a nucleotide can be regarded as a phosphoester of a nucleoside. A combination of nitrogenous base and a sugar is called nucleoside and combination of a base, a sugar and phosphate group is known as nucleotide.

$\text{N}_2$  base + Pentose sugar  $\rightarrow$  'Nucleoside'

Nucleoside + Phosphoric acid  $\rightarrow$  'Nucleotide' +  $\text{H}_2\text{O}$ .

Table : 3.2-1

Types of nitrogen base	Nucleoside	Nucleotide
Adenine	Adenosine	Adenylic acid
Guanine	Guanosine	Guanylic acid
Cytosine	Cytidine	Cytidilic acid
Thymine	Thymidine	Thymidylc acid
Uracil	Uridine	Uridylic acid

There are two types of pentose sugars, ribose found in RNA and deoxyribose found in DNA. There are two types of bases which occur in the nucleic acids.

(i) **Purines** : Purines are 9 membered double ringed nitrogenous bases which possess nitrogen at 1', 3', 7' and 9' positions. They are adenine (A) and guanine (G).

(ii) **Pyrimidines** : They are smaller molecule than purines. These are 6 membered single ringed nitrogenous bases that contain nitrogen at 1' and 3' positions like cytosine (C), thymine (T) and uracil (U). In DNA adenine pairs with thymine by two  $\text{H}_2$  bond and cytosine pairs with guanine by three  $\text{H}_2$  bond.

A nucleotide may have one, two or three phosphates, as one in AMP, two in ADP. The II and III phosphate bond is called high energy bond and it release about 8 K cal. ATP was discovered by Karl Lohmann (1929). Formation of ATP is endergonic reaction.

### Functions of nucleotides

❑ **Formation of nucleic acids** : Different nucleotides polymerize together to form DNA and RNA.

❑ **Formation of energy carrier** : They help in formation of ATP, AMP, ADP, GDP, GTP, TDP, TTP, UDP, etc. which on breaking release energy

❑ **Formation of Coenzymes** : Coenzymes like NAD, NADP, FMN, FAD, CoA, etc are formed

## Macromolecules

Macromolecules are polymerisation product of micromolecules, have high molecular weight and low solubility. They include mainly polysaccharide, protein and nucleic acids.

(1) **Polysaccharide** : They are branched or unbranched polymers of monosaccharides jointed by glycosidic bond. Their general formula is  $(C_6H_{10}O_5)_n$ . Polysaccharides are amorphous, tasteless and insoluble or only slightly soluble in water and can be easily hydrolysed to monosaccharide units.

### Types of polysaccharides

#### (i) On the basis of structure

**Homopolysaccharides** : These are made by polymerisation of single kind of monosaccharides. e.g., starch, cellulose, glycogen, etc.

**Heteropolysaccharide** : These are made by condensation of two or more kinds of monosaccharides. e.g., chitin, pectin, etc.

#### (ii) On the basis of functions

**Food storage polysaccharides** : They serve as reserve food. e.g., starch and glycogen.

**Structural polysaccharides** : These take part in structural framework of cell wall e.g., chitin and cellulose.

### Description of some polysaccharides

**Glycogen** : It is a branched polymer of glucose and contain 30,000 glucose units. It is also called animal starch. It is also found as storage product in blue green algae, slime moulds, fungi and bacteria. It is a non-reducing sugar and gives red colour with iodine. In glycogen, glucose molecule are linked by 1-4 glycosidic linkage in straight part and 1-6 linkage in the branching part glycogen has branch points about every 8-10 glucose units.

**Starch** ( $C_6H_{10}O_5$ ) : Starch is formed in photosynthesis and function as energy storing substance. It is found abundantly in rice, wheat, legumes, potato (oval and ecentric shaped), banana, etc. Starch is of two types. Straight chain polysaccharides known as amylose and branched chain as amylopectin. Both composed of D-glucose units jointed by  $\alpha$ -1-4 linkage and  $\alpha$ -1-6 linkage. It is insoluble in water and gives blue colour when treated with iodine.

**Inulin** : Also called "dahlia starch"(found in roots). It has unbranched chain of 30-35 fructose units linked by  $\beta$ -2-1 glycosidic linkage between 1 and 2 of carbon atom of D-fructose unit.

**Cellulose** : An important constituent of cell wall (20-40%), made up of unbranched chain of 6000  $\beta$ -D glucose units linked by 1-4 glycosidic linkage. It is fibrous, rigid and insoluble in water. It doesn't give any colour when treated with iodine. It is a most abundant polysaccharide.

**Chitin** : It is a polyglycol consisting of N-acetyl-D-glucosamine units connected with  $\beta$ -1,4 glycosidic linkage. Mostly it is found in hard exoskeleton of insects and crustaceans and some times in fungal cell wall. Second most abundant carbohydrate. It is a most abundant heteropolysaccharide.

**Agar-Agar** : It is a galactan, consisting of both D and L galactose and it is used to prepare bacterial cultures. It is also used as laxative and obtained from cell wall of red algae e.g., Gracilaria, Gelidium etc.

**Pectin** : It is a cell wall material in collenchyma tissue may also be found in fruit pulps, rind of citrus fruits etc. It is water soluble and can undergo sol  $\leftrightarrow$  gel transformation. It contain arabinose, galactose and galacturonic acid

**Neutral sugars** : It is found associated with cellulose in cell wall. The common sugars in hemicellulose are D-xylose, L-arabinose, D-galactose, D-mannose and D-glucuronic acid. e.g., hemicellulose.

**Gum** : It secreted by higher plants after injury or pathogenic attacks. It is viscous and seals the wound. It involves sugars like L-arabinose, D-galactose, D-glucuronic acid. e.g., gum arabic.

(2) **Mucopolysaccharides** : These are gelatinous substance, containing amino sugars, uronic acid, etc. All slimy substances of plant are mucopolysaccharide. e.g., hyaluronic acid, vitreous humour, chondridine sulphate, heparin, husk of Isabgol and mucilage also.

**Glycoproteins** : They include some plasmaprotein and blood group substances. They doesn't contain uronic acid.

**Murein** : It is a peptidoglycan, linked to short chains of peptides. It is constituent of cell wall of bacteria and blue green algae.

### Functions

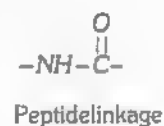
(i) Cellulose pectin and chitin are constituents in cell wall of higher plants but peptidoglycan in the cell wall of prokaryotes.

(ii) They are reserve food material and form protective covering.

(iii) Fibres obtained are used in making cloth and rope.

(iv) Nitrocellulose and trinitrate cellulose (gun-cotton) used as explosive.

(3) **Protein** : The word protein was coined by Berzelius in 1838 and was used by G. J. Mulder first time 1840. 15% of protoplasm is made up of protein. Average proteins contain 16% nitrogen, 50-55% carbon, oxygen 20-24%, hydrogen 7% and sulphur 0.3-0.5%. Iron, phosphorous, copper, calcium, and iodine are also present in small quantity.



**Structure of proteins** : It is due to different rearrangement of amino acids. When carboxyl group ( $-\text{COOH}$ ) of one amino acid binds with amino group ( $-\text{NH}_2$ ) of another amino acid the bond is called peptide bond.

(i) **Primary structure** : The primary structure is the covalent connections of a protein. It refers to linear sequence, number and nature of amino acids bonded together with peptide bonds only. e.g., ribonuclease, insulin, myoglobin and lysozyme.

(ii) **Secondary structure** : The folding of a linear polypeptide chain into specific coiled structure ( $\alpha$ -helix) is called secondary structure. This  $\alpha$  helix structure was discovered by Linus Pauling and Robert Corey (1952) using x-ray diffraction technique in silk fibres. e.g., fur, keratin of hair claws, and feathers.

(iii) **Tertiary structure** : The arrangement and interconnection of proteins into specific loops and bends is called tertiary structure of proteins. It is found in e.g., globular proteins.

(iv) **Quaternary structure** : It is shown by protein containing more than one peptide chain. The protein consists of identical units. It is known as homologous quaternary structure e.g., lactic dehydrogenase. If the units are dissimilar, it is called as heterogeneous quaternary structure e.g., haemoglobin.

**Classification of proteins** : Proteins are classified on the basis of their shape, constitution and function.

#### On the basis of shape

**Fibrous protein/Scleroprotein** : Insoluble in water. Animal protein resistant to proteolytic enzyme is spirally coiled thread like structure form fibres. e.g., collagen (in connective tissue), actin and myosin, keratin in hairs, claws, feathers, etc.

**Globular proteins** : Soluble in water. Polypeptides coiled about themselves to form oval or spherical molecules e.g., albumin insulin hormones like ACTH, oxytocin, etc.

#### On the basis of constituents

**Simple proteins** : The proteins which are made up of amino acids only. e.g., albumins, globulins, prolamines, glutelins, histones, etc.

**Conjugated proteins** : These are complex proteins combined with characteristic non-amino acid substance called as prosthetic group. These are of following types :

(i) **Nucleoproteins** : Combination of protein and nucleic acids, found in chromosomes and ribosomes. e.g., deoxyribonucleoproteins, ribonucleoproteins, etc.

(ii) **Mucoproteins** : These are combined with large amount (more than 4%) of carbohydrates e.g., mucin.

(iii) **Glycoproteins** : In this, carbohydrate content is less (about 2 – 3%) e.g., immunoglobulins or antibiotics.

(iv) **Chromoproteins** : These are compounds of protein and coloured pigments. e.g., haemoglobin, cytochrome, etc.

(v) **Lipoproteins** : These are water soluble proteins and contain lipids. e.g., cholesterol and serum lipoproteins.

(vi) **Metalloprotein** : These are metal binding proteins, AB<sub>1</sub>-globin known as transferring is capable of combining with iron, zinc and copper e.g., chlorophyll.

(vii) **Phosphoprotein** : They are composed of protein and phosphate e.g., casein (milk) and vitellin (egg).

**Derived proteins** : When proteins are hydrolysed by acids, alkalis or enzymes, the degradation products obtained from them are called derived proteins.

#### On the basis of nature of molecules

**Acidic proteins** : They exist as anion and include acidic amino acids. e.g., blood groups.

**Basic proteins** : They exist as cations and rich in basic amino acids e.g., lysine, arginine etc.

#### Function of Proteins

(i) Proteins occur as food reserves as glutelin, globulin casein in milk.

(ii) Proteins are coagulated in solutions, alkaline to the isoelectric pH by positive ions such as Zn<sup>2+</sup>, Cd<sup>2+</sup>, Hg<sup>2+</sup> etc. Casein – pH 4.6, cyt. C – 9.8, serum globulin 5.4, pepsin 2.7, lysozyme 11.0 etc.

(iii) Proteins are the most diverse molecule on the earth.

(iv) They are biological buffers.

(v) Monelin is the sweetest substance obtained from African berry (2000 time sweeter than sucrose).

(vi) Most abundant protein on earth is RUBP.

(vii) Myosin is structural as well as enzymatic protein (ATPase).

#### Nucleic acids

Nucleic acids are the polymers of nucleotide made up of carbon, hydrogen, oxygen, nitrogen and phosphorus and which controls the basic functions of the cell. These were first reported by Friedrich Miescher (1871) from the nucleus of pus cell. Altmann called it first time as nucleic acid. Nuclein was renamed nucleic acid by Altman in (1889). They are found in nucleus. They help in transfer of genetic information.

**Types of nucleic acids** : On the basis of nucleotides i.e., sugars, phosphates and nitrogenous bases, nucleic acids are of two types which are further subdivided. These are DNA (Deoxyribonucleic acid) and RNA (Ribonucleic acid).

(1) **DNA (Deoxyribonucleic acids)** : Term DNA was given by Zacharis

(i) **Types of DNA** : It may be linear or circular in eukaryotes and prokaryotes respectively.

**Palindromic DNA** : The DNA helix bears nucleotide in a serial arrangement but opposite in two strands.

–T–T–A–A–C–G–T–T–A–A... ..

–A–A–T–T–G–C–A–A–T–T... ..

**Repetitive DNA** : This type of arrangement is found near centromere of chromosome and is inert in RNA synthesis. The sequence of nitrogenous bases is repeated several times.

**Satellite DNA** : It may have base pairs upto 1 – 60 bp and are repetitive in nature. Microsatellite has 1 – 6 bp and minisatellite has 11 – 60 bp. They are used in DNA matching or finger printing (Jefferey). In eukaryotes, DNA is deuterotatory and sugars have pyranose configuration.

(ii) **Chargaff's rule** : Quantitatively the ratio of adenine (A) to thymine (T) and guanine (G) to cytosine (C) is equal. i.e., "Purines are always equal to pyrimidine".

(iii) **C value** : It is the total amount of DNA in a genome or haploid set of chromosomes.

(iv) **Sense and Antisense strand** : Out of two DNA strand one which carries genetic information in its cistrons is called sense strand while the other strand does not carry genetic information, therefore, doesn't produce mRNA. The non-functional DNA strand is called antisense strand.

(v) **Heteroduplex DNA** : Hybrid DNA formed as a result of recombination is called heteroduplex DNA. It contains mismatched base pair of heterologous base sequence.

**X-Ray crystallography study of DNA** : It was done by Wilkins. It shows that the two polynucleotide chains of DNA show helical configuration.

**Single stranded DNA (ssDNA)** : It is single helixed circular and isolated from bacteriophage  $\phi \times 174$  by Sinsheimer (1959). It does not follow Chargaff's rule. The replicative form (RF) has plus – minus DNA helix. e.g., parvovirus.

**Double helical model of DNA**: It is also known as Watson and Crick model.

(2) **RNA or Ribonucleic acid** : RNA is second type of nucleic acid which is found in nucleus as well as in cytoplasm i.e., mitochondria, plastids, ribosomes etc. They carry the genetic information in some viruses. They are widely distributed in the cell. Genomic RNA was discovered by Franklin and Conrat (1957).

## History of cellular enzymes

Enzymes (Gk. *en* = in; *zyme* = yeast) are proteinaceous substances which are capable of catalysing chemical reactions of biological origins without themselves undergoing any change. Enzymes are **biocatalysts**. Enzymes exist inside the cell in colloidal form. An enzyme may be defined as "a protein that enhances the rate of biochemical reactions but does not affect the nature of final product". Like the catalyst the enzymes regulate the speed and specificity of a reaction, but unlike the catalyst they are produced by living cells only. All components of cell including cell wall and cell membrane have enzymes.

Maximum enzymes (70%) in the cell are found in mitochondrion. Enzymes are also called '**biological middle man**'. The study of the composition and function of the enzyme is known as **enzymology**.

The term enzyme (meaning in yeast) was used by Willy Kuhne (1878) while working on fermentation. At that time living cells of yeast were thought to be essential for fermentation of sugar. Edward Buchner (1897), a German chemist proved that extract zymase, obtained from yeast cells, has the power of fermenting sugar (alcoholic fermentation). Zymase is complex of enzymes (Buchner isolated enzyme for the first time).

Later J.B. Sumner (1926) prepared a pure crystalline form of urease enzyme from Jack Bean (*Canavalia ensiformis*) and suggested that enzymes are proteins. Northrop and Kunitz prepared crystals of pepsin, trypsin and chymotrypsin. Arber and Nathans got noble prize in 1978 for the discovery of restriction endonucleases which break both strands of DNA at specific sites and produce sticky ends. These enzymes are used as microscissors in genetic engineering.

## Nature of enzymes

Mostly enzymes are proteinaceous in nature. With some exception all enzymes are proteins but all proteins are not enzymes. Enzymatic protein consist of 20 amino acids. The polypeptide chain or chains of an enzyme show tertiary structure. Their tertiary structure is very specific and important for their biological activity. Loss of tertiary structure renders the enzymic activity.

Some enzymes like pepsin, amylase, urease, etc., are exclusively made up of protein i.e., simple proteins. But most of the other enzymes have a protein and a non-protein component, both of which are essential for enzyme activity. The protein component of such enzymes is known as **apoenzyme** whereas the non-protein component is called **cofactor** or **prosthetic group**. The apoenzyme and prosthetic group together form a complete enzyme called **holoenzyme**.

Activity of enzyme is due to co-factor, which can be separated by dialysis. co-factor is small, heat stable and may be organic or inorganic in nature.

Three types of cofactors may be identified. Prosthetic group, coenzyme and metal ions.

**Prosthetic group** : Prosthetic groups are organic compounds distinguished from other cofactors in that they are permanently bound to the apoenzyme, e.g., in peroxisomal enzymes peroxidase and catalase which catalyzes breakdown of hydrogen peroxide to water and oxygen.

**Coenzymes** : Fritz Lipmann discovered coenzymes. Coenzymes are also organic compounds but their association with the apoenzyme is transient, usually occurring only during the course of catalysis.

In general coenzymes not only assist enzymes in the cleavage of the substrate but also serve as temporary acceptor for one of the product of the reaction. The essential chemical component of many coenzymes are vitamins, e.g., coenzyme nicotinamide adenine dinucleotide (NAD), nicotinamide adenine dinucleotide phosphate (NADP) contains the vitamin niacin, coenzyme A contains pantothenic acid, flavin mononucleotide (FMN), flavin adenine dinucleotide (FAD) contains riboflavin (Vitamin B<sub>2</sub>), and thiamine pyrophosphate (TPP) contains thiamine (Vitamin B<sub>1</sub>).

**Metal ions** : A number of enzymes require metal ions for their activity. The metal ions form coordination bonds with specific side chains at the active site and at the same time form one or more coordination bonds with the substrate. The latter assist in the polarization of substrate bonds to be cleaved by the enzyme. The common metal ions are Zn<sup>++</sup>, Cu<sup>++</sup>, Mg<sup>++</sup>.

Inorganic part of enzyme acts as prosthetic group in few enzymes they are called activators. These activators are generally metals. Hence these enzymes are called Metalloenzyme such as

**Table : 3.2-2 Enzymes activators**

Activators	Enzymes
Iron (Fe)	Acetone, Catalase and Cytochrome oxidase
Zinc (Zn)	Alcohol dehydrogenase, Carbonic anhydrase
Copper (Cu)	Tyrosinase, Cytochrome oxidase
Magnesium (Mg)	Hexokinase, Phosphotransferase
Manganese (Mn)	Peptidase, Decarboxylase
Molybdenum (Mo)	Nitrate reductase
Nickel (Ni)	Urease
Boron	Enolase

## Nomenclature and Classification

Daudlax, (1883) introduced the nomenclature of enzyme. Usually enzyme names end in suffix-**ase** to the name of substrate e.g., Lactase acts on lactose, maltase act on maltose, amylase on amylose, sucrase on sucrose, protease on proteins, lipase on lipids and cellulase on cellulose. Sometimes arbitrary names are also popular e.g., Pepsin, Trypsin and Ptylin etc. Few names have been assigned on the basis of the source from which they are extracted e.g., Papain from papaya, bromelain from pineapple (family Bromeliaceae). Enzymes can also be named by adding suffix-**ase** to the nature of chemical reaction also e.g., Oxidase, dehydrogenase, catalase, DNA polymerase.

Modern names are given after chemical action. They are more systematic, informative but slightly longer. e.g., ATP : D-glucose phosphotransferase.

Common simpler names used at the place of systematic names called **trivial names**

**According to older classification :** The older classification of enzymes is based on the basis of reactions which they catalyse. Many earlier authors have classified enzymes into two groups :

(i) **Hydrolysing enzyme :** The hydrolysing enzymes of hydrolases catalyse reactions in which complex organic compounds are broken into simpler compounds with the addition of water. Hydrolytic reactions are reversible. Depending upon the substrate hydrolysing enzymes are :

**Carbohydrases :** Most of the polysaccharides, disaccharides or small oligosaccharides are hydrolysed to simpler compounds, e.g., hexoses or pentoses under the influence of these enzymes.

Lactase on lactose to form glucose to galactose, sucrase/invertase on sucrose to form glucose and fructose, amylase or diastase on starch to form maltose, maltase on maltose to form glucose, cellulase on cellulose to produce glucose.

**Esterases :** These enzymes catalyse the hydrolysis of substances containing ester linkage, e.g., fat, pectin, etc. into an alcoholic and an acidic compound.

Fat  $\xrightarrow{\text{Lipase}}$  Glycerol + Fatty acid

Phosphoric acid esters  $\xrightarrow{\text{Phosphatase}}$

Phosphoric acid + Other compounds

**Proteolytic enzymes :** The hydrolysis of proteins into peptones, polypeptides and amino acids is catalysed by these enzymes

Protein  $\xrightarrow{\text{Pepsin}}$  Peptones

Polypeptides  $\xrightarrow{\text{Peptidase}}$  Amino acids

**Amidases :** They hydrolyse amides into ammonia and acids.

Urea  $\xrightarrow{\text{Urease}}$  Ammonia + Carbon dioxide

Asparagine  $\xrightarrow{\text{Asparaginase}}$  Ammonia + Aspartic acid

(2) **Desmolysing enzymes :** Most of the desmolysing enzymes are the enzymes of respiration e.g., oxidases, dehydrogenases, (concerned with transfer of electrons), transaminases carboxylases etc.

**According to IUB system to classification :** In 1961 the Commission on enzymes set up by the 'International Union of Biochemistry' (IUB) framed certain rules of their nomenclature and classification.

According to IUB system of classification the major points are :

□ Reactions (and enzymes catalyzing them) are divided into 6 major classes each with 4-13 subclasses.

□ The enzyme name has two parts-first name is of substrate. The second ending in **ase** indicates type of reaction.

□ The enzyme has a systematic code No. (Enzyme code/Enzyme Commission). The first digit denotes the class, the second sub-class, the third sub-sub-class and the fourth one is for the particular enzyme name. Thus, E.C. 2.7.1.1 denotes class 2 (Transferases)-subclass 7 (transfer of phosphate) sub-sub-class 1 (an alcohol functions as phosphate acceptor). The 4<sup>th</sup> digit indicates hexokinase. Major classes of enzymes are as follows :

(i) **Oxidoreductases :** These enzymes catalyse **oxidation reduction** reactions, usually involving the transfer of hydrogen atoms or ions from one molecule to another. There are three main types of these enzymes :

**Oxidases :** Where the hydrogen is transferred from a molecule to oxygen, e.g., cytochrome oxidase. They play very important role in E.T.S. in photosynthesis as well as respiration,

**Dehydrogenases :** Where the hydrogen is transferred to a coenzyme such as NAD<sup>+</sup>, e.g., Succinic dehydrogenase. They help in oxidation of organic molecules during aerobic respiration.

**Reductase :** It is cause of addition of hydrogen or an electron and remove oxygen. e.g., Nitrate reductase requires NAD (coenzyme I) as coenzyme for the reaction.

(ii) **Transferases :** These enzyme catalyse the transfer of a specific group (e.g., amino, methyl, acyl, phosphate) from one kind of molecule to another e.g., transphosphorylases, transaminases, transpeptidases, transmethylnases, kinases, etc.

(iii) **Hydrolases :** These enzyme catalyse the hydrolysis of organic foods i.e., the breakdown of large molecules by addition of water. Most of the hydrolysing (digestive) enzymes are located in lysosomes. e.g., all digestive enzymes such as lipases (digest the stored food material of castor seeds) amylases, esterases, phosphatases, carbohydrases, proteases.

(iv) **Lyases (Desmolases) :** These enzymes catalyse the breakage of specific covalent bonds and removal of groups without hydrolysis e.g., fumerases, carboxylases, aminases, histidine decarboxylase that splits C-C-bond of histidine, forming CO<sub>2</sub> and histamine.

(v) **Isomerases :** These enzymes catalyse the rearrangement molecular structure to form isomers. e.g., phosphohexose isomerase (phosphoglucumutase) act on glucose 6-phosphate to form fructose 6-phosphate (both C<sub>6</sub> compounds); epimerase, racemase.

(vi) **Ligases or Synthetases :** These enzymes form bonds and join two molecules together, using energy supplied from the breakdown of ATP, e.g., DNA ligase is used to repair breaks in DNA molecules. Amino-Acyl synthetase is used to activate t-RNA by attaching amino acid at 3' end. Tryptophan synthetase is used to convert tryptophan amino acid to IAA.

## Site of enzyme action

All enzymes are produced in the living cells. About 3,000 enzymes have recorded. These are of two types with regard to the site where they act as :

**Intracellular enzymes :** Most of the enzymes remain and function inside the cells. They are called the intracellular enzymes or endoenzymes. Some of these enzymes are found in cytoplasmic matrix. Certain enzymes are bound to ribosomes, mitochondria and chloroplast etc.

**Extracellular enzymes :** Certain enzymes leave the cells and function outside them. They are called the extracellular enzymes or exoenzymes. They mainly include the digestive enzymes. e.g., salivary amylase, gastric pepsin, lysozyme present in tears and nasal secretion.

Rennet tablets with enzyme rennin from calf's stomach are widely used to coagulate protein caseinogen for cheese (casein) formation.

## Mechanism of enzyme action

Energy is required to bring the inert molecules into the activated state. The amount of energy required to raise the energy of molecules at which chemical reaction can occur is called **activation energy**. Enzymes act by decreasing the activation energy so that the number of activated molecules is increased at lower energy levels. If the activation energy required for the formation of the enzyme-substrate complex is low, many more molecules can participate in the reaction than would be the case if the enzyme were absent.

## Mode of enzyme action

In 1913 Michaelis and Menten proposed that for a catalytic reaction to occur it is necessary that enzyme and substrate bind together to form an enzyme substrate complex.



It is amazing that the enzyme-substrate complex breaks up into chemical products different from those, which participated in its formation (i.e., substrates). On the surface of each enzyme there are many specific sites for binding substrate molecules called **active sites** or catalytic sites.

There are two views regarding the mode of enzyme action :

**Lock and Key hypothesis (Template hypothesis) :** The hypothesis was put forward by Emil Fisher (1894). According to this hypothesis the enzyme and its substrate have a complementary shape. The specific substrate molecules are bound to a specific site of the enzyme molecule.

The theory can be explained easily by the fact that a particular lock can be opened by a particular key specially designed to open it. Similarly enzymes have specific sites where a particular substrate can only be attached. The lock and key model accounts for enzyme specificity.

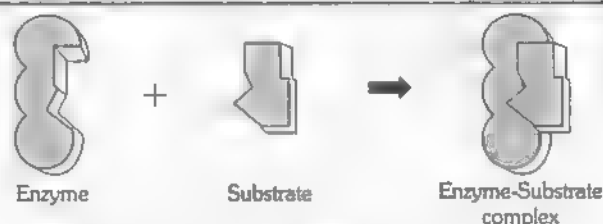


Fig : 3.2-1 Lock and key model of enzyme action

**Induced fit hypothesis :** This hypothesis was proposed by Daniel, E. Koshland (1959).

According to this view, active site is not rigid but static and it has two groups – buttressing group and catalytic group. Initially substrate bind to the buttressing group which induces the catalytic group to fit the substrate and catalytic group weakens the bonds of reactant or substrate by electrophilic and nucleophilic forces.

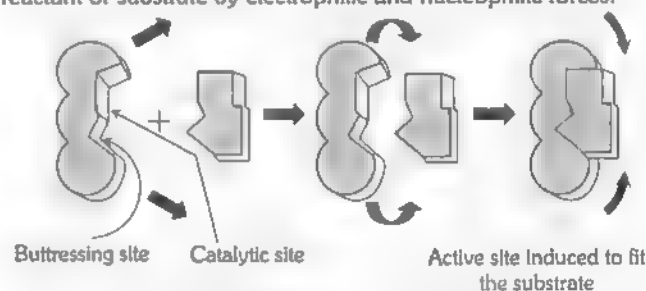


Fig : 3.2-2 Induced fit model of enzyme action

## Properties of enzymes

**Molecular weight :** Enzymatic proteins are substances of high molecular weight. Bacterial ferredoxin one of the smaller enzymes has molecular weight of 6,000, where as pyruvic dehydrogenase one of the largest-has a molecular weight of 4600000.

**Amphoteric nature :** Each molecule of enzyme possess numerous groups which yield  $H^+$  in slightly alkaline solutions and groups which yield  $OH^-$  ions in slightly acidic solutions. Unlike many other substances, therefore, the enzymatic protein is amphoteric, i.e., capable of ionizing either as an acid or as a base depending upon the acidity of the external solution.

**Colloidal nature :** All enzymes are colloidal in nature and thus provide large surface area for reaction to take place. They posses extremely low rates of diffusion and form colloidal system in water.

**Specificity of enzyme :** Most of the enzymes are highly specific in their action. A single enzyme will generally catalyze only a single substrate or a group of closely related substrates. The active site possess a particular binding site which complexes only with specific substrate. Thus, only a suitable substrate fulfils the requirements of active site and closely fixes with it. The specificity of enzyme is determined by sequence of amino acids in the active sites.

**Heat specificity :** The enzymes are thermolabile i.e., heat sensitive. They function best at an optimum temperature ( $20^\circ\text{C}$ - $40^\circ\text{C}$ ). Their activity decrease with decrease as well as increase in temperature and stops at  $0^\circ\text{C}$  and above  $80^\circ\text{C}$ .

**Catalytic properties :** Enzymes are active in extremely small amounts, e.g., one molecule of invertase can effectively hydrolyze 1,000,000 times its own weight of sucrose. One molecule of catalase is able to catalyze conversion of 5,000,000 molecules of hydrogen peroxide.

**Reversibility of reaction :** The enzyme-controlled reactions are reversible. The enzymes affect only the rate of biochemical reactions, not the direction. e.g., Lipase can catalyze splitting of fat into fatty acids and glycerol as well as synthesis of fatty acids and glycerol into fats.



**pH sensitivity :** The enzymes show maximum activity at an optimum pH is 6 – 7.05 ( $7 \pm 1.05$ ). Their activity slows with decrease and increase in pH till it stops. Each enzyme has its own different favourable pH value.

**High efficiency :** The effectiveness of an enzymatic reaction is expressed in terms of its turn over number or catalytic centre activity means number of substrate molecules on which one enzymes molecules acts in one minute.

Turn over number depends on the number of active sites of an enzyme. An active site is an area of the enzyme which is capable of attracting and holding particular substrate molecules by its specific charge, size and shape so as to allow the chemical change. Enzymes show 3-D structure. R (alkyl) groups of amino acids form active sites during folding polypeptide chains. Usually 3-12 amino acids form an active site.

Highest turn over number is of **carbonic anhydrase** (36 million/min or 600000 per second) and lowest is of **lysozymes** (30/min or 0.5 per second). So carbonic anhydrase is fastest enzyme. The lowest turn over number is of lysozymes.

## Enzyme inhibition

**Competitive inhibition :** Substances (Inhibitors) which are structurally similar to the substrates and competes for the active site of the enzyme are known as competitive inhibitors. Usually such inhibitors show a close structural resemblance to the substrates to the enzyme they inhibit. In such a case, inspite of enzyme substrate complex, enzyme inhibitor complex is formed and enzyme activity is inhibited

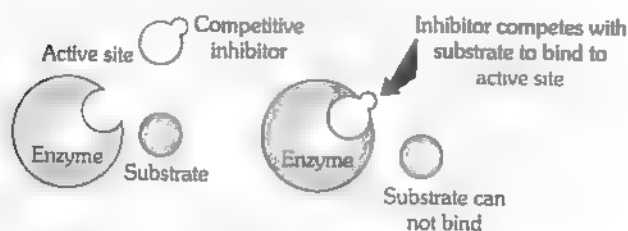


Fig : 3.2-3 Competitive Inhibition

The concentration of EI complex depends on the concentration of free inhibitor. Because EI complex readily dissociates, the empty active sites are then available for substrate binding. The effect of a competitive inhibitor on activity is reversed by increasing the concentration of substrate. In it  $V_{max}$  remain constant and  $K_m$  increases.

A classic example of competitive inhibition is succinic acid dehydrogenase which oxidises succinic acid to fumaric acid. If concentration of malonic acid, is added, the activity of succinic dehydrogenase decreases rapidly. Hence malonic acid acts as a competitive inhibitor since it has structural resemblance to succinic acid

The competitive inhibition can be reversed by increasing the concentration of the substrate. Competitive inhibitors are used in control of bacterial pathogens.

**Non-competitive inhibition :** These substances (poisons) do not combine with active sites but attach somewhere else and destroy the activity of enzyme.

Both EI and ES complexes are formed. Inhibitor binding alters the three dimensional configuration of the enzyme and thus blocks the reaction. Non competitive inhibitor do not competes directly with the substrate for binding to the enzyme. In it  $V_{max}$  in lowered and  $K_m$  is changed.

The non-competitive inhibition can not be reversed by increasing the concentration of the substrate i.e., Irreversible. e.g., cyanide inhibits the mitochondrial enzyme cytochrome oxidase which is essential for cellular respiration. This kills the animals.

More AMP is a non competitive inhibitor of fructose biphosphate phosphatase, the enzyme that catalyzes the conversion of fructose 1, 6 biphosphate to fructose 6 phosphate.

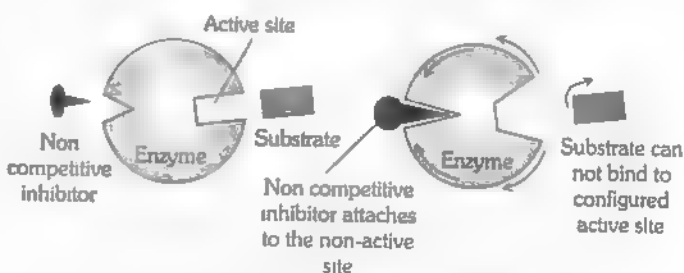


Fig : 3.2-4 Non-competitive inhibition

**Feedback inhibition :** In number of cases, accumulation of the final product of the reaction is capable of inhibiting the first step of reaction.



The product P checks the activity of enzyme which converts A into B. It is quite useful mechanism because it checks the accumulation of products.



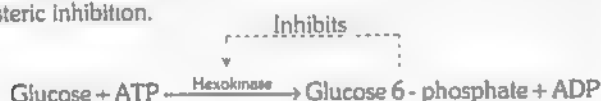
The phenomenon in which the end product of a metabolic pathway can regulate its own production by inhibition of the sort is called **feed back inhibition** or negative feed back inhibition. This type of inhibition can be shown in *Escherichia coli* bacterium which synthesises the amino acid isoleucine from a substrate threonine by a series of intermediate reactions (i.e.,  $\alpha$  ketobutyrate threonine deaminase,  $\alpha$  Aceto hydroxy butyrate,  $\alpha$  keto  $\beta$  methyl valerate etc).

When isoleucine accumulates in amounts more than required, it stops its own production by inhibiting the activity of the enzyme. Threonine deaminase which catalyzes the first reaction of the series. This type of metabolic control in which the first enzyme of a series is inhibited by the end product, is known as end product inhibition.

**Allosteric inhibition (Modulation)** : Allosteric literally means 'another place'. Still other inhibitors join an enzyme at a specific site and change the form of the active site meant for the substrate. These inhibitors are known as modifiers or modulators and the sites where they fit in are called allosteric sites. Modulators are of two types-positive (activators) and negative (inhibitors).

Change of active site which prevent the binding of substrate to the enzyme and stops the reaction. The process is called allostery or allosteric inhibition. The enzyme with allosteric sites are called allosteric enzymes. Jacob and Monod have termed this phenomenon as allosteric transition.

An example of allosteric enzyme inhibition is hexokinase that converts glucose to glucose 6-phosphate. Glucose 6-phosphate causes allosteric inhibition of hexokinase. This is called feedback allosteric inhibition.



### Some terms regarding enzymes

**Zymogens or (Enzyme Precursors)** : Certain enzymes are produced by the living cells in an inactive (non-functional) form. They are called the zymogens or proenzymes. It is then converted, usually by proteolysis (hydrolysis of the protein), to the active form when it has reached the site of its activity. Pepsinogen and trypsinogen are zymogens produced by gastric glands and pancreas respectively. They are necessary to life because they degrade dietary proteins into amino acids that are used by the cell.

**Isoenzymes (Isozymes)** : There are certain enzymes which have slightly different molecular structure but performing the same catalytic function. Such enzymes are called isoenzymes or simply isozymes. Isoenzyme of an enzyme differ from each another in their amino acid sequence, molecular weight, immunological and electrophoretic behaviours. Hence, they can be separated by electrophoresis.

More than 100 enzymes are known to have isoenzyme. A good example of isoenzyme is lactic dehydrogenase (LDH). It catalyzes change of pyruvate to lactate.

**Inducible enzymes** : An enzyme which is synthesized only in the presence of its substrate (inducer) is called inducible enzyme e.g.,  $\beta$ -galactosidase.

**Constitutive enzymes (House keeping enzyme)** : The enzyme which are found in constant amounts under different growth conditions (regardless of its metabolic states) are called constitutive enzyme e.g., enzymes of sugar breakdown i.e., glycolysis.

**Repressible enzymes** : The presence of a specific substance may inhibit continued production of specific enzyme (enzyme repressor) e.g., glucokinase.

**Ribozymes** : Study of post transcriptional processing of RNA molecules has led to the most exciting discovery of the existence of some catalytic RNA molecules which have been called as RNA enzymes or ribozymes. All enzymes are not proteins as confirmed by Cech (1981) and Altman (1983). Ribozyme and RNAase-P are two non protein enzyme where RNA acts as catalyst. Ribozyme was reported from Tetrahymens (a protozoans) by Cech. The substrate for ribozyme is usually an RNA molecule. RNAase-P (Ribonuclease) was discovered by Altman.

Peptidyl transferase is also a non-proteinaceous enzyme, discovered by Noller.

**Michaelis constant** : Michaelis and Menten (1913) introduced a constant  $K_m$  (Michaelis constant).

It is a mathematical derivative or constant which indicates the substrate concentration at which the chemical reaction catalysed by an enzyme attains half its maximum velocity ( $V_{max}$ ).

$K_m$  indicates affinity of the enzyme for its substrate.

$$K_m = \frac{1}{2} V_{max}$$

$K_m$  value differs from substrate to substrate because different enzymes differ in their affinity towards different substrates. A high  $K_m$  indicates low affinity while a low  $K_m$  shows strong affinity. Protease acts on different proteins. So its  $K_m$  value will differ from protein to protein.

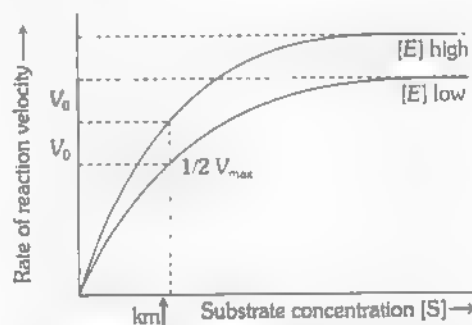


Fig : 3.2-5 Reaction velocity 'V' and substance concentration (S) for a typical enzyme catalysed reaction

The Michaelis Menten equation describe how reaction relatively varies with substrate concentration as given

$$V_0 = \frac{V_{max}[S]}{K_m + [S]}$$

Where  $V_0$  is the rate of initial reaction;  $V_{max}$  is the maximum relative or the reaction rate with excess substrate;  $K_m$  is the Michaelis constant  $= K_2 + K_3/K_1$ ;  $[S]$  is the substrate concentration.



The above reaction shows that the greater the affinity between an enzyme and its substrate, the lower the  $K_m$  (in units moles per litre) of the enzyme substrate reaction. Stated inversely,  $1/K_m$  is the measure of affinity of the enzyme for its substrate.

**Enzyme-inhibitor dissociation constant ( $K_i$ ) :** It is dissociation constant of enzyme – inhibitor complex.

$$K_i = \frac{[E][I]}{[EI]}$$

Where, E is enzyme and I is concentration of inhibitor.

High  $K_i$  decreases enzyme activity while low  $K_i$  increases some, it is applicable to competitive inhibitors.

### Factors affecting the enzyme activity

**Substrate concentration :** If there are more enzyme molecules than substrate molecules, a progressive increase in the substrate molecules increases the velocity of their conversion to products. However, eventually the rate of reaction reaches the maximum. At this stage the active sites of all the available enzyme molecules are occupied by the substrate molecules. Therefore, the substrate molecules occupy the active sites vacated by the products and cannot increase the rate of reaction further.

**Enzyme concentration :** The rate of reaction is directly proportional to enzyme concentration. An increase in enzyme concentration will cause a rise in the rate of reaction upto a point and then the rate of reaction will be constant. Increasing the enzyme concentration increases the number of available active sites.

**Product concentration :** Accumulation of the product of enzyme reaction lowers the enzyme activity. Enzyme molecules must be freed to combine with more substrate molecules. Normally the product are quickly removed from the site of formation and the reaction does not suffer.

**Hydrogen ion concentration ( $pH$ ) :** Some enzyme act best in an acid medium, other in an alkaline medium, for every enzyme there is an optimum  $pH$  where its action is maximum e.g., 2 for pepsin, 6.8 for salivary amylase, 8.5 for trypsin. Most enzyme show maximum activity in a  $pH$  range of about 6.0 to 7.5 i.e., near neutral  $pH$  (endoenzymes). A shift to the alkaline or acid side rapidly decreases the enzyme activity and finally stops it altogether. This is due to denaturation of enzyme molecule i.e., change in its physical structure.

**Temperature :** Within certain limits ( $5-40^\circ C$ ) the rate of an enzyme catalyzed reaction increases as the temperature increases. The  $Q_{10}$  of most enzymatic reactions is 2, i.e., every  $10^\circ C$  rise in temperature doubles the rate of reaction. Most enzymes show maximum activity in a temperature range of  $25$  to  $40^\circ C$ . Beyond this temperature, there is sharp fall in the rate of reaction. Above  $50^\circ C$  they get denatured completely.

Modification in the physical form of the enzyme results in the loss of its catalytic activity. This change in structure is called **denaturation** of protein. This is the permanent change, and the denatured enzyme protein remains inactive even if the temperature is then brought down. The enzymes are not destroyed by freezing, and regain their lost activity if the temperature is raised to normal.

Deep freezing of food for preserving them for long periods is done not only to prevent the growth and multiplication of microorganisms but also to inactivate enzymes. It makes impossible for the microorganisms to digest the food. Below freezing point enzymes become inactive but do not get denatured.

**Enzyme Inhibitors :** Certain chemical compounds inhibit activity of enzyme molecules either permanently or temporarily. Thus, diisopropyl fluorophosphate (DFP) inhibits the action of various enzymes catalysing hydrolysis of ester linkage. Inhibition is permanent or irreversible.

**Poisons and Radiation :** Poisons such as cyanide and radiation destroy the tertiary structure of the enzymes, making them ineffective

## Tips & Tricks

- ✚ Most of the vitamins of B complex group act as coenzyme.
- ✚ Myosin a structural component of muscle. It has ATPase activity also.
- ✚ Synthesis of enzymes occur in polysome (aggregation of ribosomes).
- ✚ cAMP mediated cascade model of enzyme regulation was proposed by Sutherland.
- ✚ Competitive inhibitor increase Michaelis constant ( $K_m$ ) but it has no effect on  $V_{max}$ .
- ✚ Regulators of metabolism are enzymes, vitamins and hormones.
- ✚ RNA polymerase enzyme form RNA from DNA and DNA polymerase is responsible for synthesis of DNA from DNA.
- ✚ Enzyme that catalyses the conversion of soluble proteins into insoluble ones, process is called enzyme coagulation.
- ✚ Albinism is caused by the deficiency of tyrosinase.
- ✚ Iron porphyrin coenzyme or cofactor is cytochrome.
- ✚ Nitrogenase enzyme is inactivated by oxygen.
- ✚ Nitrogenase enzyme is responsible for the reduction of molecular nitrogen to the level of ammonia in leguminous root nodule
- ✚ Nitrate reductase enzyme is responsible for the formation of  $NO_2^-$ .
- ✚ Amylopsin acts upon polysaccharide in alkaline medium.
- ✚ Due to enzymatic transformations huge amount of starch is deposited in potato tubers.
- ✚ Tertiary structure of protein component of enzyme is destroyed by a number of factors like heat, high energy radiation and salts of heavy metals (e.g.,  $Ag^+$ ,  $Hg^{2+}$ ,  $As^{3+}$ ).
- ✚ Some enzyme are active at very high temperature ( $70-80^\circ C$ ) called **extremozyme** e.g., Taq polymerase.
- ✚ Smallest enzyme is peroxidase and largest being catalase found in peroxisome.

# **Ordinary Thinking**

## **Objective Questions**

### **Carbohydrates, Starch and Protein**

- Starch and cellulose are the compounds made up of many units of [CPMT 1993, 2003, 09]
  - Simple sugar
  - Fatty acid
  - Glycerol
  - Amino acid
- Which one of the following is the sweetest sugar or laevo-rotatory sugar [AFMC 2002; MP PMT 2007]
 

Or

 Inulin is a polymer of [WB JEE 2011]
  - Fructose
  - Glucose
  - Galactose
  - Sucrose
- Which of the following is the characteristic of plants [MP PMT 2003]
  - Glucose and cellulose
  - Pyruvic acid and glucose
  - Cellulose and starch
  - Starch and pyruvic acid
- Observe the following figure and identify A and B bonds in the diagrammatic representation of a portion of glycogen [NCERT]
 
  - A = 1-4  $\alpha$  - glycosidic bonds, B = 1-4  $\alpha$  - glycosidic bonds
  - A = 1-1  $\alpha$  - glycosidic bonds, B = 1-1  $\alpha$  - glycosidic bonds
  - A = 1-6  $\alpha$  - glycosidic bonds, B = 1-4  $\alpha$  - glycosidic bonds
  - A = 1-4  $\alpha$  - glycosidic bonds, B = 1-6  $\alpha$  - glycosidic bonds
- Inulin found in plant cell is a [Odisha PMT 2002; WB JEE 2012; AIIMS 2012]
  - Lipid
  - Protein
  - Polysaccharide
  - Vitamin
- Pentoses and hexoses are the most common [BHU 2002]
 

Or

 The simple polyhydroxy ketone molecule containing 3-7 carbons is a [Kerala PMT 2006]
  - Disaccharides
  - Monosaccharides
  - Oligosaccharides
  - Polysaccharides
- Corn is immersed in the boiling water. It is then cooled, the solution becomes sweet. It is due to [AFMC 1999; JIPMER 2001]
  - Enzymes are inactivated in boiling water
  - Disaccharides are converted to monosaccharides
  - Monosaccharides are converted to disaccharides
  - None of these

- Cholesterol belongs to which of the following groups [Odisha JEE 2008; J & K CET 2012]
  - Steroids
  - Neutral fats
  - Waxes
  - Phospholipids
- Which one of the following diagrams shows a molecule of simple lipid [NCERT]
 

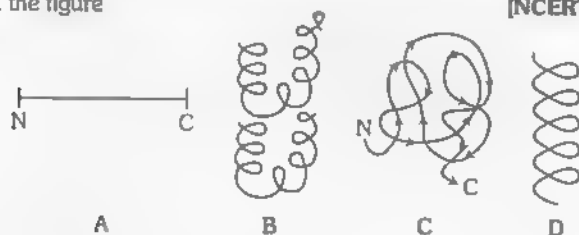
(a)

(b)

(c)

(d)
- The alpha helices and beta sheets are the example of which level of protein organization [J & K CET 2012]
  - Primary structure
  - Secondary structure
  - Tertiary structure
  - Quaternary structure
- Sucrose, a common table sugar, is composed of [Odisha JEE 2004; CPMT 2009]
  - Glucose + fructose
  - Glucose + galactose
  - Fructose + galactose
  - None of these
- Which is non-reducing sugar [Odisha JEE 2004; Bihar CECE 2005; CBSE PMT 2014]
  - Glucose
  - Galactose
  - Mannose
  - Sucrose
- Sugar and amino acids are [MHCET 2004]
  - Primary metabolites
  - Secondary metabolites
  - Feed stock
  - Inoculum
- A complex polysaccharide produced from sucrose by the bacterium *Leuconostoc mesenteroides* is [BHU 2004]
  - Chitin
  - Starch
  - Cellulose
  - Dextran
- The chemical formula of starch is [RPMT 2002]
  - $(C_6H_{10}O_5)_n$
  - $(C_6H_{12}O_6)_n$
  - $C_{12}H_{22}O_{11}$
  - $CH_3COOH$
- Oval shaped and eccentric starch particles are found in [RPMT 1995]
  - Wheat
  - Maize
  - Potato
  - Rice
- Which one of the following conjugate protein [Odisha PMT 2002]
  - Globulin
  - Albumin
  - Histone
  - Flavoprotein
- Glycoproteins contain [KCET 2000]
  - Protein and fat
  - Protein and salt
  - Protein and vitamin
  - Protein and carbohydrates

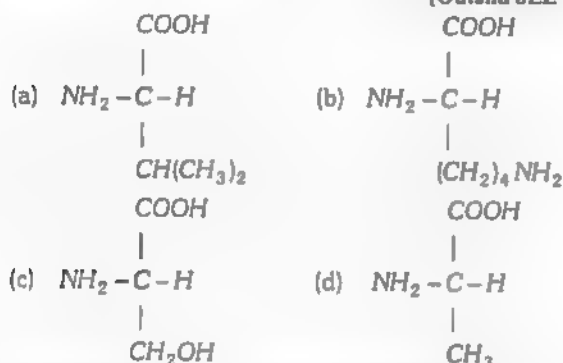
19. See the following figure and identify the structure of proteins in the figure [NCERT]



- (a) A = 4° structure, B = 3° structure, C = 2° structure, D = 1° structure  
 (b) A = 1° structure, B = 4° structure, C = 3° structure, D = 2° structure  
 (c) A = 4° structure, B = 2° structure, C = 3° structure, D = 1° structure  
 (d) A = 1° structure, B = 2° structure, C = 3° structure, D = 4° structure

20. Which one of the following is a basic amino acid

[Odisha JEE 2012]



21. Largest physical and chemical molecules are

[CBSE PMT 1996]

Or

What are the most diverse molecules in the cell

[MP PMT 2000]

Or

No cell could live without

[MP PMT 1997]

- (a) Carbohydrates (b) Lipids  
 (c) Proteins (d) Nucleic acids

22. Find out the wrongly matched pair

[Kerala PMT 2010]

- (a) Primary metabolite - Ribose  
 (b) Secondary metabolite - Anthocyanins  
 (c) Protein - Insulin  
 (d) Chitin - Polysaccharide  
 (e) Cellulose - Heteropolymer

23. Lipids are Insoluble in water, because lipids molecules are

[CBSE PMT 2002]

- (a) Neutral (b) Zwitter ions  
 (c) Hydrophobic (d) Hydrophilic

24. Which one of the following statements is wrong

[NEET (Phase-I) 2016]

- (a) Sucrose is a disaccharide  
 (b) Cellulose is a polysaccharide  
 (c) Uracil is a pyrimidine  
 (d) Glycine is a sulphur containing amino acid

25. Which of the following is conjugated protein [MHCET 2000]

- (a) Chromoproteins (b) Phosphoprotein  
 (c) Glycoprotein (d) All of the above

26.  $\alpha$ -helical model of protein was discovered by

[BVP 2000; MHCET 2001]

- (a) Pauling and Corey (b) Watson  
 (c) Morgan (d) Berzelus

27. Which one of the following biomolecules is correctly characterised [NCERT; CBSE PMT (Mains) 2012]

- (a) Lecithin - a phosphorylated glyceride found in cell membrane  
 (b) Palmitic acid - an unsaturated fatty acid with 18 carbon atoms  
 (c) Adenylic acid - adenosine with a glucose phosphate molecule  
 (d) Alanine amino acid - Contains an amino group and an acidic group anywhere in the molecule

28. High content of lysine is present in

[MHCET 2003]

- (a) Wheat (b) Apple  
 (c) Maize (d) Banana

29. Example of a typical homopolysaccharide is [WB JEE 2011]

- (a) Lignin (b) Suberin  
 (c) Inulin (d) Starch

30. Arachidonic acid is

[MHCET 2003]

- (a) Non-essential fatty acid (b) Essential fatty acid  
 (c) Polyunsaturated fatty acid (d) Both (b) and (c)

31. The two polypeptides of human insulin are linked together by [NEET (Phase-I) 2016]

- (a) Hydrogen bonds (b) Phosphodiester bond  
 (c) Covalent bond (d) Disulphide bridges

32. Which of the following carbon is anomeric in glucose

[BHU 2012]

- (a) C<sub>1</sub> (b) C<sub>2</sub>  
 (c) C<sub>4</sub> (d) None of these

33. During strenuous exercise glucose is converted into [BHU 2005]

- (a) Glycogen (b) Pyruvic acid  
 (c) Starch (d) Lactic acid

34. In which form does the food transported in plants

[BHU 2005]

- (a) Sucrose (b) Fructose  
 (c) Glucose (d) Lactose

35. Which of the following fatty acids is liquid at room temperature [NCERT; AMU (Med.) 2012]

- (a) Palmitic acid (b) Stearic acid  
 (c) Oleic acid (d) Linoleic acid

36. Match the following and choose the correct combination from the options given

Column I  
(Organic Compound)

Column II  
(Example)

- A. Fatty acid  
 B. Phospholipid  
 C. Aromatic amino acid  
 D. Acidic amino acid

1. Glutamic acid  
 2. Tryptophan  
 3. Lecithin  
 4. Palmitic acid

[NCERT; Kerala PMT 2012]

- (a) A-1, B-2, C-3, D-4  
 (c) A-2, B-3, C-4, D-1  
 (e) A-4, B-3, C-1, D-2

- (b) A-4, B-3, C-2, D-1  
 (d) A-3, B-4, C-1, D-2

37. Which of the following amino acids is not optically active [BHU 2005]

(a) Glycine (b) Valine  
(c) Leucine (d) Isoleucine

38. Paraffin wax is [BHU 2006]

(a) Ester (b) Acid  
(c) Monohydric alcohol (d) Cholesterol

39. Match the items in column I with those in column II and choose the correct answer

**Column I**  
(Biomolecules)

A. Carbohydrates  
B. Protein  
C. Nucleic acid  
D. Lipid

**Column II**  
(Examples)

1. Trypsin  
2. Cholesterol  
3. Insulin  
4. Adenylic acid

[Kerala PMT 2012]

(a) A-3, B-1, C-4, D-2 (b) A-2, B-3, C-4, D-1  
(c) A-3, B-4, C-1, D-2 (d) A-4, B-1, C-2, D-3  
(e) A-1, B-2, C-3, D-4

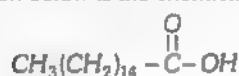
40. Match the items in column I with items in column II and choose the correct answer

Column I		Column II	
A.	Triglyceride	1.	Animal hormones
B.	Membrane lipid	2.	Feathers and leaves
C.	Steroid	3.	Phospholipids
D.	Wax	4.	Fat stored in form of droplets

[Kerala PMT 2006]

(a) A-4, B-3, C-1, D-2  
(b) A-2, B-3, C-4, D-1  
(c) A-3, B-4, C-1, D-2  
(d) A-4, B-1, C-2, D-3  
(e) A-4, B-3, C-2, D-1

41. Given below is the chemical formula of



[NCERT; Kerala PMT 2007]

(a) Palmitic acid (b) Stearic acid  
(c) Glycerol (d) Galactose  
(e) Fumaric acid

42. Find out the mis-matched pair [Kerala PMT 2007]

(a) Agar - Polymer of glucose and sulphur containing carbohydrates  
(b) Chitin - Polymer of glucosamine  
(c) Peptidoglycan - Polysaccharide linked to peptides  
(d) Lipopolysaccharides - A complex of lipid and polysaccharide  
(e) Glycogen - Polymer of glucose

43. Select the wrong statement [Kerala PMT 2007]

(a) The building blocks of lipids are amino acids  
(b) Majority of enzymes contain a non-protein part called the prosthetic group  
(c) The thylakoids are arranged one above the other like a stack of coins forming a granum  
(d) Crossing-over occurs at pachytene stage of meiosis I  
(e) Steroids are complex compounds commonly found in cell membranes and animal hormones

44. Match the following with correct combination

Column - I		Column - II	
A.	Triglycerides	1.	Galactose
B.	Lactose	2.	Glycerol
C.	RNA	3.	Palmitic acid
D.	$\beta$ pleats	4.	Uracil
E.	Beewax	5.	Secondary structure

[Kerala PMT 2007]

(a) A-4, B-1, C-5, D-2, E-3  
(b) A-5, B-1, C-4, D-2, E-3  
(c) A-3, B-1, C-4, D-5, E-2  
(d) A-2, B-1, C-4, D-5, E-3  
(e) A-3, B-1, C-4, D-2, E-5

45. Which of the following is not a disaccharide

[KCET 1999; DPMT 2007]

(a) Maltose (b) Starch  
(c) Sucrose (d) Lactose

46. What does the following equation denote? Amino acid + ATP  $\rightarrow$  Aminoacyl AMP + PP [DPMT 2007]

(a) Elongation of chain (b) Chain termination  
(c) Activation of amino acid (d) None of these

47. Which of the following is not a conjugated protein [WB JEE 2010]

(a) Peptone (b) Phosphoprotein  
(c) Lipoprotein (d) Chromoprotein

48. Which of the following fats is least harmful for heart

[DPMT 2007]

(a) Saturated fat (b) Cholesterol  
(c) Polyunsaturated fat (d) Oils

49. Protein denaturation takes place by the activity of

[Odisha JEE 2008]

Or

Enzymes are sensitive to [MP PMT 1999]

(a) Water (b) Heat  
(c) Enzyme (d) Pressure

50. In a polysaccharide, the individual monosaccharides are linked by a [AMU (Med.) 2011; Kerala PMT 2011]

(a) Glycosidic bond (b) Peptide bond  
(c) Ester bond (d) Phosphodiester bond  
(e) Hydrogen bond

51. Select the incorrect statement [Kerala PMT 2011]

(a) Amino acids are substituent methanes  
(b) Glycerol is a trihydroxy propane  
(c) Lysine is a neutral amino acid  
(d) Lecithin is a phospholipid  
(e) Adenosine is a nucleoside

52. Carbohydrates are commonly found as starch in plant storage organs. Which of the following five properties of starch (A-E) make it useful as a storage material

(A) Easily translocated  
(B) Chemically non-reactive  
(C) Easily digested by animals  
(D) Osmotically inactive  
(E) Synthesized during photosynthesis

The useful properties are : [CBSE PMT 2008]

(a) (A), (C) and (E) (b) (A) and (E)  
(c) (B) and (C) (d) (B) and (D)

53. Which of the following promotes softening of fruits

[Kerala PMT 2008]

(a) Polygalacturonase (b) Colchicine  
(c) Polyethylene glycol (d) Cellulase  
(e) Brazzein

54. Which of the following statements is/are not true

(A) Glycerol is a 3 carbon alcohol with 3 OH groups that serve as binding sites  
(B) Waxes are esters formed between a long chain alcohol and saturated fatty acids  
(C) The term protein was coined by Gerardus Johannes Mulder  
(D) Agar is an indispensable polysaccharide and it is a complex polymer of glucose and sulphur-containing carbohydrates

[Kerala PMT 2008]

(a) (A) and (C) only (b) (A) and (D) only  
(c) (A), (B) and (D) only (d) (A), (C) and (D) only  
(e) (D) only

55. Which is an organic compound found in most cells

[DUMET 2009]

Or

Most common monomer of carbohydrate is

[Odisha JEE 2008]

Or

The "repeating unit" of glycogen is

[WB JEE 2009]

(a) Glucose (b) Water  
(c) Sodium chloride (d) Oxygen

56. Quaternary structure of protein [NCERT; WB JEE 2008]

(a) Consists of four subunits  
(b) May be either  $\alpha$  or  $\beta$   
(c) Is unrelated to two function of the protein  
(d) Is dictated by the primary structures of the individual subunits

57. Which of the following carbohydrates is not a disaccharide

[WB JEE 2008]

(a) Maltose (b) Lactose  
(c) Sucrose (d) Galactose

58. Chitin is a

[WB JEE 2010; NEET 2013]

(a) Polysaccharide  
(b) Nitrogenous polysaccharide  
(c) Lipoprotein  
(d) Protein

59. Which of the following is the least likely to be involved in stabilizing the three-dimensional folding of most proteins

[NEET (Phase-II) 2016]

(a) Ester bonds (b) Hydrogen bonds  
(c) Electrostatic interaction (d) Hydrophobic interaction

60. Which of the followings can bring about the denaturation of proteins

[WB JEE 2016]

(a) Reaction to salts of heavy metals  
(b) Reaction to acid and bases  
(c) Reaction to inorganic neutral salts  
(d) Preservation at a temperature below  $-5^{\circ}\text{C}$

### Nucleotides and Nucleic acid

1. A ribose (but not deoxyribose) nucleotide is

[Kerala PMT 2004]

(a) Cytosine — pentose sugar — phosphate  
(b) Guanine — pentose sugar — phosphate  
(c) Thymine — pentose sugar — phosphate  
(d) Uracil — pentose sugar — phosphate

2. DNA is present in

[NCERT; MP PMT 1995, 96, 98;

BVP 2000; RPMT 2001; MHCET 2001; AIIMS 2004]

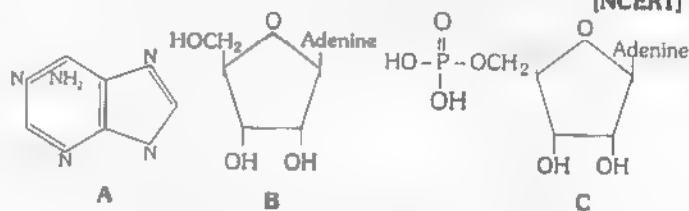
Or

Which one of the following has its own DNA

[CBSE PMT (Pre.) 2010]

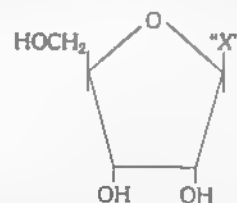
(a) Nucleus only (b) Mitochondrion only  
(c) Chloroplast only (d) All the above

3. See the following figure and identify the correct combination [NCERT]



	A	B	C
(a)	Uracil	Adenosine (Nucleoside)	Adenylic acid (Nucleotide)
(b)	Adenosine (Nucleoside)	Adenylic acid (Nucleotide)	Adenine (N - base)
(c)	Adenine (N - base)	Adenosine (Nucleoside)	Adenylic acid (Nucleotide)
(d)	Adenine (N - base)	Adenosine (Nucleotide)	Adenylic acid (Nucleoside)

4. Given below is the diagrammatic representation of one of the categories of small molecular weight organic compounds in the living tissues. Identify the category shown and the one blank component "X" in it [NCERT; CBSE PMT (Pre.) 2012]



Category

Component

(a) Cholesterol Guanin  
(b) Amino acid  $\text{NH}_2$   
(c) Nucleotide Adenine  
(d) Nucleoside Uracil

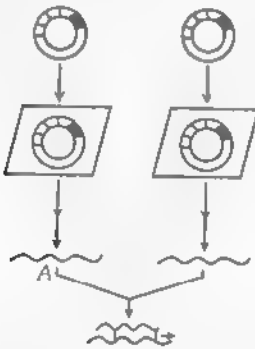
5. DNA is a polymer of [CPMT 1998; BVP 2000]  
Or  
Which is the ultimate unit of DNA molecule [MH CET 2005]  
(a) Nucleotide (b) Nucleoside  
(c) Amino acids (d) All of the above
6. How many nucleotides are present in one turn of DNA helix [NCERT; MP PMT 1999, 2000; HPMT 2005; Odisha JEE 2011]  
(a) 4 pairs (b) 8 pairs  
(c) 10 pairs (d) 9 pairs
7. ATP is [Odisha PMT 2002; MP PMT 2004, 05]  
(a) Adenosine D-ribose three phosphate  
(b) Adenosine L-ribose three phosphate  
(c) Adenine D-ribose three phosphate  
(d) Adenine L-ribose three phosphate
8. Which of the following is correct pair of pyrimidine bases [MHCET 2015]  
(a) Adenine and Thymine (b) Adenine and Guanine  
(c) Thymine and Cytosine (d) Guanine and Cytosine
9. Thymine is a  
(a) Enzyme (b) Vitamin  
(c) Pyrimidine (d) Purine
10. Name the elements which occur in nucleic acid macromolecule [Kerala PMT 2006]  
(a) C, H, O, N, S (b) C, O, N, S  
(c) C, O, P, S (d) C, H, O, N, P  
(e) H, O, P
11. Nucleoside is made up of [BHU 1995; BCECE 2001; Pb. PMT 2004]  
(a) Sugar only (b) Phosphate only  
(c) Sugar and phosphate (d) Sugar and base
12. Strands of DNA are bonded by [NECRT]  
(a) Hydrogen (b) Carbon  
(c) Oxygen (d) Nitrogen
13. RNA and ATP contains [KCET 1994, 2009; BVP 2000; CPMT 2003]  
(a) Hexose sugar (b) Deoxyribose sugar  
(c) Dextrose sugar (d) Ribose sugar
14. Nucleic acid occurs in [KCET 2007]  
(a) Golgi body  
(b) Lysosomes  
(c) Cytoplasm  
(d) Mitochondria and chloroplast
15. Which of the following is not a pyrimidine [MP PMT 2007]  
(a) Thymine (b) Uracil  
(c) Guanine (d) Cytosine
16. DNA is not present in one of the following [MP PMT 2003]  
(a) Mitochondria (b) Chloroplast  
(c) Bacteriophage (d) Tobacco mosaic virus
17. DNA strands are antiparallel because of the presence of [Kerala PMT 2004]  
(a) H-bonds (b) Peptide bonds  
(c) Disulphide bonds (d) Phosphate-diester bonds  
(e) None of the above
18. Examine the following figures and select the right answer in which diagrammatic representation of a nucleotide is correctly shown [NCERT]
- (a)

(b)

(c)

(d)
19. Which of the following bases is present in RNA in place of thymine [NCERT; CPMT 1996, 2003; MP PMT 1998, 2001, 10; Pb PMT 2000; Odisha JEE 2004; J & K CET 2005, 08; Kerala PMT 2009, 11]  
(a) Uracil (b) Adenine  
(c) Guanine (d) Water
20. Nucleic acids were discovered by [MP PMT 1999]  
Or  
DNA was first discovered by [CPMT 1994]  
(a) Watson and Crick (b) Khorana  
(c) Wilkins (d) Miescher
21. In DNA molecule, which of the following base pair is present [MP PMT 1992]  
(a) Cytosine and adenine (b) Adenine and thymine  
(c) Adenine and guanine (d) Cytosine and thymine
22. The given diagram shows the nitrogenous bases. Identify the correct combination [NCERT]
- A

B
- (a) A = Guanine; B = Uracil  
(b) A = Adenine; B = Uracil  
(c) A = Guanine; B = Thymine  
(d) A = Adenine; B = Thymine
23. The transformation experiments on *Pneumococcus* showed that  
(a) DNA can duplicate itself  
(b) RNA is the genetic material  
(c) DNA is the genetic material  
(d) None of these
24. The base pairs of DNA are correctly shown as [Bihar MDAT 1995; RPMT 1997; BHU 1998, 99, 2004; BVP 2000; MHCET 2003; MP PMT 2013]  
(a) A = T and C = G (b) A = T and C = G  
(c) A = T and C = G (d) A = T and C = G

25. Which one of the following is widely distributed in a cell [MHCET 2000]  
 (a) DNA (b) RNA  
 (c) Chloroplast (d) Chromoplast
26. Which of the cell organelles are devoid of deoxy ribonucleic acid [RPMT 1997]  
 (a) Mitochondria and nucleus  
 (b) Chloroplast and mitochondria  
 (c) Nucleus and chloroplast  
 (d) Lysosome and dictyosome
27. The similarity between DNA and RNA is that both are [KCET 1999, 2006]  
 (a) Double stranded  
 (b) Having similar sugars  
 (c) Polymers of nucleotides  
 (d) Having similar pyrimidines
28. What indicated "A" in given figure [GUJCET 2015]
- 
- (a) Peptide bond (b) Glycosidic bond  
 (c) Disulfide bond (d) Hydrophobic bond
29. Which of the following biomolecules does have phosphodiester bond [AIPMT 2015]  
 (a) Monosaccharides in a polysaccharide  
 (b) Amino acids in a polypeptide  
 (c) Nucleic acids in a nucleotide  
 (d) Fatty acids in a diglyceride
30. Ultraviolet light absorbed by nucleic acid is [RPMT 2000]  
 (a) 26 nm (b) 75 nm  
 (c) 260 nm (d) 1500 nm
31. The length of DNA having 23 base pairs is [Kerala PMT 2004; WB JEE 2009]  
 (a) 70 Å (b) 78.4 Å  
 (c) 78.2 Å (d) 74.8 Å  
 (e) 74.2 Å
3. Enzymes are basically or All enzymes contain [NCERT; MP PMT 1995, 2000, 04, 05; CBSE PMT 2000; BVP 2002; MHCET 2003; Odisha JEE 2009]  
 (a) Sugars (b) Proteins  
 (c) Fats (d) Vitamins
4. "Enzymes are proteins", it was suggested by  
 (a) Miller (b) Sumner  
 (c) Pasteur (d) Leeuwenhock
5. Who got the Nobel prize working on enzymes in the year 1978 [MP PMT 1997]  
 (a) W. Arber and D. Nathans  
 (b) Nass and Nass  
 (c) R. Misra  
 (d) H.G. Khorana
6. To explain the mechanism of enzymatic action, who proposed "Lock and key hypothesis" [CPMT 1996; MP PMT 1998, 2010, 12; BHU 2000; RPMT 2002]  
 (a) Fischer (b) Jacob  
 (c) Koshland (d) Sumner
7. Many of the hydrolytic reactions are [BHU 2001]  
 (a) Reversible (b) Irreversible  
 (c) Endothermic (d) Exothermic
8. The "lock and key" model of enzyme action illustrates that a particular enzyme molecule [DUMET 2009, 10]  
 (a) May be destroyed and resynthesized several times  
 (b) Interacts with a specific type of substrate molecule  
 (c) Reacts at identical rates under all conditions  
 (d) Forms a permanent enzyme-substrate complex
9. Enzymes were discovered for the first time in [Pb. PMT 1995]  
 (a) Yeast (b) Maize  
 (c) Bacteria (d) Algae
10. Who discovered 'co-enzymes'  
 (a) James Sumner (b) Fritz Lipmann  
 (c) Mayerhoff (d) Edward Buchner
11. A competitive inhibitor of succinic dehydrogenase is [NCERT; CBSE PMT 2008]  
 (a)  $\alpha$ -ketoglutarate (b) Malate  
 (c) Malonate (d) Oxaloacetate
12. An example of feedback inhibition is [Kerala PMT 2008]  
 (a) Cyanide action on cytochrome  
 (b) Sulpha drug on folic acid synthesizer bacteria  
 (c) Allosteric inhibition of hexokinase by glucose 6-phosphate  
 (d) Reaction between succinic dehydrogenase and succinate  
 (e) The inhibition of succinic dehydrogenase by malonate
13. Who proposed the principal of "Induced fit" [BHU 1998]  
 (a) Jacob (b) Fischer  
 (c) Koshland (d) Laderberg
14. The molecules that are well recognized as biocatalysts in addition to enzymes are [AFMC 2012]  
 (a) Polysaccharides (b) Fatty acids  
 (c) RNAs (d) None of these

### Introduction, properties, action and inhibition of enzyme

1. Who first used the term "enzyme" [CPMT 2004]  
 (a) J.B. Sumner (b) Kuhne  
 (c) Thompson (d) Garnier
2. Who coined the term zymase for enzymes in yeast [BHU 2002]  
 (a) Kuhne (b) Sumner  
 (c) Louis pasteur (d) Edward Buchner

15. Enzymes are the polymers of [MP PMT 1994]  
Or  
Which of the following is polymerized to form proteins [MHCET 2003]  
Or  
An enzyme can be synthesised by chemically bonding together molecules of [AFMC 1994]  
(a) Hexose carbon (b) Fatty acids  
(c) Amino acids (d) Inorganic phosphate
16. Telomerase is an enzyme which is a [AIIMS 2005]  
(a) Simple protein (b) RNA  
(c) Ribonucleoprotein (d) Repetitive DNA
17. Which one of the following statements is incorrect [AIPMT (Cancelled) 2015]  
(a) In competitive inhibition, the inhibitor molecule is not chemically changed by the enzyme  
(b) The competitive inhibitor does not affect the rate of breakdown of the enzyme-substrate complex  
(c) The presence of the competitive inhibitor decreases the  $K_m$  of the enzyme for the substrate  
(d) A competitive inhibitor reacts reversibly with the enzyme to form an enzyme-inhibitor complex
18. An example of non-competitive inhibition is [Kerala PMT 2009]  
(a) The inhibition of succinic dehydrogenase by malonate  
(b) Cyanide action on cytochrome oxidase  
(c) Sulpha drug on folic acid synthesizing bacteria  
(d) The inhibition of hexokinase by glucose 6-phosphate  
(e) Reaction of succinic dehydrogenase
19. Enzymes are absent in [CBSE PMT 2000; AFMC 2003]  
(a) Algae (b) Fungi  
(c) Bacteria (d) Virus
20. Feedback inhibition of enzymes is affected by which of the following [WB JEE 2009]  
Or  
Jacob and Monod named those enzymes *allosteric* whose activity is regulated by  
(a) Enzyme (b) Substrate  
(c) End products (d) Intermediate end products
21. Non-proteinaceous enzyme that acts as a catalyst for the formation of peptide bond is [MHCET 2000; MP PMT 2007; AMU (Med.) 2010; NEET (Phase-II) 2016]  
Or  
"All enzymes are proteins." This statement is now modified because an apparent exception to this biological truth is [DUMET 2010]  
(a) Spliceosome (b) Ribozyme  
(c) RNA poly I (d) RNA poly III
22. Which one of the following statements regarding enzyme inhibition is correct [CBSE PMT 2005]  
(a) Competitive inhibition is seen when a substrate competes with an enzyme for binding to an inhibitor protein  
(b) Competitive inhibition is seen when the substrate and the inhibitor compete for the active site on the enzyme  
(c) Non-competitive inhibition of an enzyme can be overcome by adding large amount of substrate  
(d) Non-competitive inhibitors often bind to the enzyme irreversibly
23. In which one of the following enzymes, is copper necessarily associated as an activator [CBSE PMT 2004]  
(a) Lactic dehydrogenase (b) Tyrosinase  
(c) Carbonic anhydrase (d) Tryptophanase
24.  $K_m$  is related to [BHU 2000]  
(a) Morphology (b) ABO blood group  
(c) ES complex (d) Chromatography
25. Arrange the steps of catalytic action of an enzyme in order and choose the right option  
(A) The enzyme releases the products of the reaction and the enzyme is free to bind to another substrate  
(B) The active site of enzyme is in close proximity of the substrate and breaks the chemical bonds of the substrate  
(C) The binding of substrate induces the enzyme to alter its shape fitting more tightly around the substrate  
(D) The substrate binds to the active site of the enzyme fitting into the active site [Kerala PMT 2010]  
(a) (D), (C), (B), (A) (b) (C), (B), (A), (D)  
(c) (D), (B), (A), (C) (d) (B), (A), (D), (C)  
(e) (C), (D), (A), (B)
26. Select the option which is not correct with respect to enzyme action [CBSE PMT 2014]  
(a) A non-competitive inhibitor binds the enzyme at a site distinct from that which binds the substrate  
(b) Malonate is a competitive inhibitor of succinic dehydrogenase  
(c) Substrate binds with enzyme at its active site  
(d) Addition of lot of succinate does not reverse the inhibition of succinic dehydrogenase by malonate
27. Inhibition of acetylcholine by DEP (Diisopropyl-fluorophosphate) is an example of [AMU (Med.) 2012]  
(a) Competitive inhibition  
(b) Non-competitive inhibition  
(c) Non-competitive irreversible inhibition  
(d) Allosteric inhibition
28. The catalytic efficiency of two different enzymes can be compared by the [CBSE PMT 2005]  
(a) Formation of the product  
(b) The pH of optimum value  
(c) The  $K_m$  value  
(d) Molecular size of the enzyme
29. Which one of the following enzyme contains Mn metallic ion as the prosthetic group [BHU 2000]  
Or  
Which of the following enzyme is not used in making detergent [DPMT 2007]  
(a) Phosphatase (b) Dehydrogenase  
(c) Peptidase (d) Catalase
30. Three of the following statements about enzymes are correct and one is wrong. Which one is wrong [CBSE PMT (Malna) 2010; NEET (Karnataka) 2013]  
(a) Enzymes require optimum pH for maximal activity  
(b) Enzymes are denatured at high temperature but in certain exceptional organisms they are effective even at temperatures 80°-90°C  
(c) Enzymes are highly specific  
(d) Most enzymes are proteins but some are lipids



31. Which type of reaction is shown by the following figure [NCERT]



Or

Formation of both peptide and glycosidic bonds involves

[DUMET 2010]

- (a) Hydration (b) Denaturation  
(c) Dehydration (d) Hydrolysis
32. Transition state structure of the substrate formed during an enzymatic reaction is [NEET 2013]  
(a) Permanent and stable (b) Transient but stable  
(c) Permanent but unstable (d) Transient and unstable
33. An organic substance bound to an enzyme and essential for its activity is called [CBSE PMT 2006; AIIMS 2009]  
Or  
Non-protein part of an enzyme is known as [AFMC 1997; Odisha PMT 2002; BVP 2003]  
(a) Apoenzyme (b) Isoenzyme  
(c) Coenzyme (d) Holoenzyme
34. An enzyme acts by [MP PMT 1992; AIEEE Pharmacy 2003]  
(a) Reducing the energy of activation  
(b) Increasing the energy of activation  
(c) Decreasing the pH  
(d) Increasing the pH
35. The protein part of enzyme is known as [MP PMT 1996; AIIMS 2000; BVP 2000; Odisha JEE 2012; AFMC 2012]  
Or  
The enzyme which combines with non-protein part to form a functional enzyme known as [BHU 2004]  
(a) Holoenzyme (b) Apoenzyme  
(c) Isoenzyme (d) All of the above
36. Which enzyme shows greatest substrate specificity [CPMT 2005]  
(a) Nuclease (b) Trypsin  
(c) Sucrase (d) Pepsin
37. Which one of the following statements is correct with reference to enzymes [Odisha JEE 2009; KCET 2011; NEET 2017]  
(a) Apoenzyme = Holoenzyme + Coenzyme  
(b) Holoenzyme = Apoenzyme + Coenzyme  
(c) Coenzyme = Apoenzyme + Holoenzyme  
(d) Holoenzyme = Coenzyme + Co-factor
38. Number of active sites in allosteric enzyme is [CPMT 2000]  
(a) One (b) Two  
(c) Three (d) Four
39. Which one value is required for better enzymatic action [BHU 1995, 2000]  
(a) High  $K_i$  (b) Low  $K_i$   
(c) Low  $K_m$  (d) High  $K_m$
40. Cofactor (prosthetic group) is a part of holoenzyme. It is [CBSE PMT 1997; Odisha JEE 2011]  
(a) Loosely attached inorganic part  
(b) Accessory non-protein substance attached firmly  
(c) Loosely attached organic part  
(d) None of these
41. The permeases are [MP PMT 2003]  
(a) Structural membrane proteins  
(b) Enzymatic membrane proteins  
(c) Carrier membrane proteins  
(d) None of these

42. Which one of the following is not true for enzymes

[WB JEE 2012]

- (a) They act on a specific substrate  
(b) They are made up of fat and sugar  
(c) They act at a specific temperature  
(d) They act at a specific pH
43. Co-enzyme is [BHU 1994; NEET 2013]  
(a) Always a protein  
(b) Often a vitamin  
(c) Always an inorganic compound  
(d) Often a metal
44. Which of the following enzyme can form RNA from DNA [MP PMT 1992]  
(a) Restriction enzyme (b) DNA polymerase  
(c) RNA polymerase (d) Reverse transcriptase
45. Inhibitory effect of melonic acid on succinic dehydrogenase enzyme is [NCERT; AIIMS 2003]  
(a) Competitive inhibition  
(b) Non-competitive inhibition  
(c) Feedback inhibition  
(d) Inhibition due to end product
46. Lactose operon is considered to be glucose sensitive due to [DPMT 2003]  
(a) Catabolite induction (b) Allosteric inhibition  
(c) Anabolic inhibition (d) None of these
47. FAD or FMN is a coenzyme. Which vitamin is incorporated into its structure [AIIMS 2009]  
(a) Vitamin C (b) Vitamin B<sub>1</sub>  
(c) Vitamin B<sub>6</sub> (d) Vitamin B<sub>2</sub> (Riboflavin)
48. Which of the following enzymes has/have haem as a prosthetic group [Kerala PMT 2011]  
(i) Catalase (ii) Carboxypeptidase  
(iii) Succinic dehydrogenase (iv) Peroxidase  
(a) (i) Only (b) (i) and (ii)  
(c) (ii) and (iii) (d) (iii) and (iv)  
(e) (i) and (iv)
49. Which of the following is not a co-enzyme [CPMT 2004; WB JEE 2010]  
(a) NAD (b) NADP  
(c) FAD (d) ATP
50. Enzymes capable of changing their form are called [DPMT 2003]  
(a) Apoenzyme (b) Holoenzyme  
(c) Isoenzyme (d) Allosteric enzymes
51. Enzymes as they exist inside the cell are [MP PMT 1993]  
(a) In solid form (b) In crystalline form  
(c) In colloidal form (d) In solution form
52. Select the type of enzyme involved in the following reaction [Kerala PMT 2011]  
$$S-G + S' \rightarrow S + S'-G$$
  
(a) Dehydrogenase (b) Transferase  
(c) Hydrolase (d) Lyase  
(e) Isomerase

53. Template theory of enzyme action is supported by [BVP 2003]

- (a) Enzymes occur in living beings and speed up certain reactions
- (b) Enzymes speed up reaction
- (c) Enzymes determine the direction of reaction
- (d) Compounds similar to substrate inhibit enzyme activity

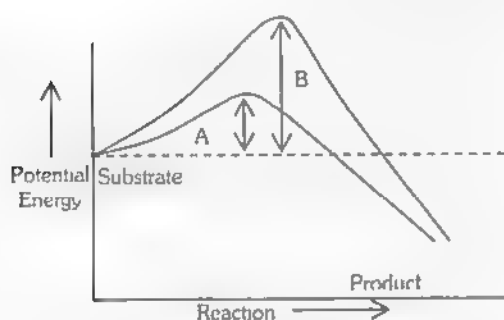
54. Decline in the activity of the enzyme hexokinase by glucose 6-phosphate is caused by [Kerala CET 2003]

- (a) Non-competitive (b) Competitive inhibitions
- (c) Allosteric modulator (d) Denaturation of enzymes

55. During glycolysis enzyme hexokinase changes glucose to glucose-6-phosphate. Glucose-6-phosphate is inhibited by [CBSE PMT 1996]

- (a) Feedback inhibition (b) Positive feedback
- (c) Competitive inhibition (d) Non-competitive inhibition

56. Which of the following describes the given graph correctly [NEET (Phase-II) 2016]



- (a) Exothermic reaction with energy A in absence of enzyme and B in presence of enzyme
- (b) Endothermic reaction with energy A in presence of enzyme and B in absence of enzyme
- (c) Exothermic reaction with energy A in presence of enzyme and B in absence of enzyme
- (d) Endothermic reaction with energy A in absence of enzyme and B in presence of enzyme

### Classification and factors affecting enzyme

1. Enzymes that catalyse inter-conversion of optical, geometrical or positional isomers are [DUMET 2009]

- (a) Ligases (b) Lyases
- (c) Hydrolases (d) Isomerases

2. Systematic approach of naming enzymes has been recommended by the Commission on Enzymes of the

- (a) International Union of Physiology
- (b) International Union of Biochemistry
- (c) International Union of Biotechnology
- (d) International Union of Genetic Engineering

3. Basically how many types of enzymes have been recognised by International Union of Biochemistry [MHCET 2000]

- (a) 4 (b) 5
- (c) 6 (d) 8

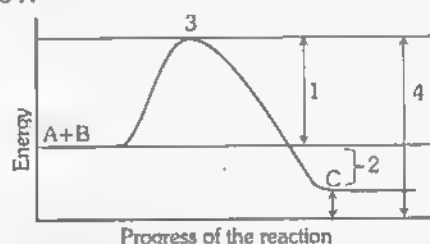
4. In the modern system of nomenclature which one of the following enzyme occupies 1st position

- (a) Oxidoreductase (b) Transferase
- (c) Hydrolase (d) Ligase

5. The plant proteinases or endopeptidases enzyme is [CPMT 1994]

- (a) Urease (b) Papain
- (c) Pepsin (d) Trypsin

6. See the following figure and identify 1, 2, 3 and 4 from the list I to IV



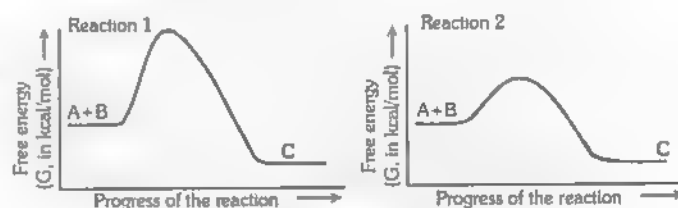
- I. Segment representing the energy of activation
- II. Segment representing the amount of free energy released by the reaction
- III. Transition state
- IV. Segment would be the same regardless of whether the reaction were uncatalysed or catalysed. Which one is correct [NCERT]

	I	II	III	IV
(a)	1	2	4	3
(b)	1	3	2	4
(c)	1	2	3	2
(d)	1	3	2	4

7. Zymogens are

- (a) Enzyme acting upon starch
- (b) Group of zymase enzymes
- (c) Inactive enzyme precursors
- (d) None of the above

8. The two chemical reactions are showing in the following figure. Which statement is correct for reaction 1 [NCERT]



- (a) Slower and more exergonic than 2
- (b) Slower and more endergonic than 2
- (c) Faster and more exergonic than 2
- (d) Faster and more endergonic than 2

9. At the time of cotton seeds germination, the stored food is digested by [CPMT 1996]

Or

Which one of the following enzyme is composed of simple proteins

- (a) Diastase (b) Maltase
- (c) Lipase (d) Amylase

10. Fat is hydrolysed by enzyme lipase to yield  
[RPMT 2002; CBSE PMT 2004; MP PMT 2012]

(a) Fatty acid and amino acids  
(b) Glycerol and fatty acids  
(c) Glycerine and water  
(d) Glycerol and amino acids

11. Substrate of amylase enzyme is [J & K CET 2005]

(a) Protein (b) Fat  
(c) Starch (d) Sucrose

12. Enzyme which hydrolyses starch to maltose is  
[MP PMT 1999]

(a) Lactase (b) Protease  
(c) Maltase (d) Amylase

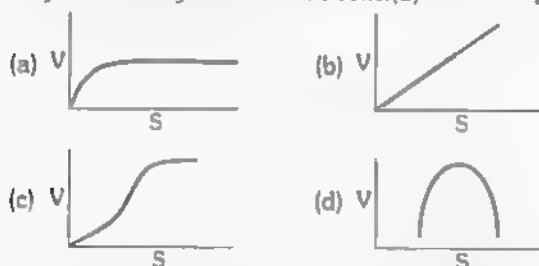
13. Which one is not an example for hydrolases  
[Kerala PMT 2004]

Or

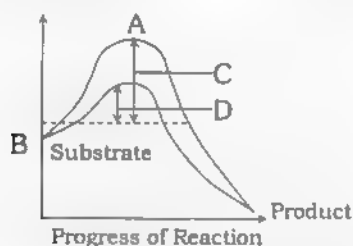
Hydrogen is removed from a substrate with the help of enzyme

(a) Dehydrogenase (b) Protease  
(c) Amylase (d) Esterase  
(e) Sucrase

14. Which graph shows the relationship between the rate of an enzymatic activity and substrate conc.(S) [NCERT]



15. The figure given below shows the conversion of a substrate into product by an enzyme. In which one of the four options (a-d) the components of reaction labelled as A, B, C and D are identified correctly



Options [NCERT; CBSE PMT (Mains) 2010]

	A	B	C	D
(a)	Potential energy	Transition state	Activation energy with enzyme	Activation energy without enzyme
(b)	Transition state	Potential energy	Activation energy without enzyme	Activation energy with enzyme
(c)	Potential energy	Transition state	Activation energy with enzyme	Activation energy without enzyme
(d)	Activation energy with enzyme	Transition state	Activation energy without enzyme	Potential energy

16. Enzyme concerned with transfer of electrons are  
[NCERT; MP PMT 1998, 2002, 03]

(a) Hydrolase (b) Dehydrogenase  
(c) Transaminase (d) Desmolase

17. Enzyme having different molecular arrangement but similar functions is [BVP 2003, 04]

Or

Enzymes which are slightly different in molecular structure but can perform identical activity are called

(a) Isoenzyme (b) Holoenzyme  
(c) Apoenzyme (d) Co-enzyme

18. Allosteric modulation is due to the inhibition action of enzyme by [Kerala PMT 2006]

(a) Competitive inhibition (b) Substrate concentration  
(c) Products of reaction (d) Enzyme concentration  
(e) Non competitive inhibition

19. Which one of the following pairs is wrongly matched  
[CBSE PMT 2009]

(a) Detergents - lipase (b) Alcohol - nitrogenase  
(c) Fruit juice - pectinase (d) Textile - amylase

20. Modern detergents contain enzyme preparations of  
[CBSE PMT 2008]

(a) Thermoacidophiles (b) Thermophiles  
(c) Acidophiles (d) Alkaliphiles

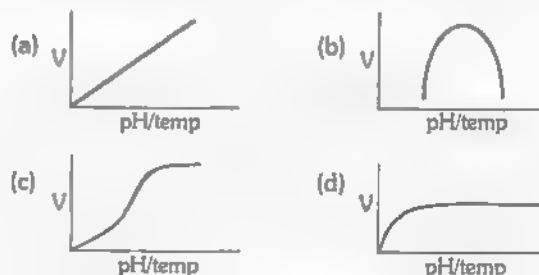
21. Signaling between cells usually results in the activation of protein [DUMET 2009]

(a) Lipases (b) Kinases  
(c) Proteases (d) Nucleases

22. With reference to enzymes, turnover number means ..... [KCET 2010]

(a) The number of substrate molecules that a molecule of an enzyme converts into products per hour  
(b) The number of substrate molecules that a molecule of an enzyme converts into products per second  
(c) The number of substrate molecules that a molecule of an enzyme convert into products per minute  
(d) The number of substrate molecules that a molecule of an enzyme converts into products per day

23. Which graph represents the effect of pH/temp on the velocity of a typical enzymatic reaction (V) [NCERT]



24. The effectiveness of an enzyme is affected least by [DUMET 2009]

(a) Temperature  
(b) Concentration of the substrate  
(c) Original activation energy of the system  
(d) Concentration of the enzyme

25. The enzyme which converts glucose into ethyl alcohol ( $C_2H_5OH$ ) is [MP PMT 1998, 2003; AMU (Med.) 2006; BHU 2006]

(a) Diastase (b) Maltase  
(c) Zymase (d) Invertase

26. The enzymes ribulose biphosphate carboxylase-oxygenase and phosphoenol pyruvate carboxylase are activated by  
[AMU (Med.) 2009]

(a) Mg (b) Zn  
(c) Mo (d) Mn

27. The curve given below show enzymatic activity with relation to three conditions (pH, temperature and substrate concentration)



What do the two axes (x and y) represent

[NCERT; CBSE PMT (Pre.) 2011]

**X-axis**

(a) Enzymatic activity  
(b) Enzymatic activity  
(c) Temperature  
(d) Substrate concentration

**Y-axis**

Temperature  
pH  
Enzyme Activity  
Enzymatic Activity

28. The nucleic acids are broken into nucleotides by.....  
enzymes [J & K CET 2002]

(a) Amylases (b) Nucleases  
(c) Lipases (d) Proteases

29. Which one of the following is wrongly matched

[Kerala PMT 2009]

(a) Fungi – Chitin  
(b) Phospholipid – Plasma membrane  
(c) Enzyme – Lipopolysaccharide  
(d) ATP – Nucleotide derivative  
(e) Antibody – Glycoprotein

30. As temperature changes from 3°C to 45°C, the rate of enzyme activity will [MP PMT 1996]

(a) Decrease and then increase (b) Increase and then decrease  
(c) Increase only (d) Decrease only

31. Which enzyme helps in removing oil stains from clothes

[BHU 2008]

Or

Which enzyme digests the stored food material of castor seeds

(a) Streptokinase (b) Trypsin  
(c) Lipase (d) Amylase



**NCERT**

**Exemplar Questions**

1. It is said that elemental composition of living organisms and that of inanimate objects (like earth's crust) are similar in the sense that all the major elements are present in both. Then what would be the difference between these two groups. Choose a correct answer from among the following [NCERT]

(a) Living organisms have more gold in them than inanimate objects  
(b) Living organisms have more water in their body than inanimate objects  
(c) Living organisms have more carbon, oxygen and hydrogen per unit mass than inanimate objects  
(d) Living organisms have more calcium in them than inanimate objects

2. Many elements are found in living organisms either free or in the forms of compounds. One of the following is not found in living organisms [NCERT]

(a) Silicon (b) Magnesium  
(c) Iron (d) Sodium

3. Aminoacids, as the name suggests, have both an amino group and a carboxyl group in their structure. In addition, all naturally occurring aminoacids (those which are found in proteins) are called L-aminoacids. From this, can you guess from which compound can the simplest aminoacid be made [NCERT]

(a) Formic acid (b) Methane  
(c) Phenol (d) Glycine

4. Many organic substances are negatively charged e.g., acetic acid, while others are positively charged e.g., ammonium ion. An aminoacid under certain conditions would have both positive and negative charges simultaneously in the same molecule. Such a form of aminoacid is called [NCERT]

(a) Positively charged form (b) Negatively charged form  
(c) Neutral form (d) Zwitterionic form

5. Sugars are technically called carbohydrates, referring to the fact that their formulae are only multiple of  $C(H_2O)$ . Hexoses therefore have six carbons, twelve hydrogens and six oxygen atoms. Glucose is a hexose. Choose from among the following another hexose [NCERT]

(a) Fructose (b) Erythrose  
(c) Ribulose (d) Ribose

6. When you take cells or tissue pieces and grind them with an acid in a mortar and pestle, all the small biomolecules dissolve in the acid. Proteins, polysaccharides and nucleic acids are insoluble in mineral acid and get precipitated. The acid soluble compounds include aminoacids, nucleosides, small sugars etc. When one adds a phosphate group to a nucleoside one gets another acid soluble biomolecule called [NCERT]

(a) Nitrogen base (b) Adenine  
(c) Sugar phosphate (d) Nucleotide

7. When we homogenise any tissue in an acid the acid soluble pool represents [NCERT]

(a) Cytoplasm (b) Cell membrane  
(c) Nucleus (d) Mitochondria

8. The most abundant chemical in living organisms could be [NCERT]

(a) Protein (b) Water  
(c) Sugar (d) Nucleic acid

9. A homopolymer has only one type of building block called monomer repeated 'n' number of times. A heteropolymer has more than one type of monomer. Proteins are heteropolymers made of aminoacids. While a nucleic acid like DNA or RNA is made of only 4 types of nucleotide monomers, proteins are made of [NCERT]

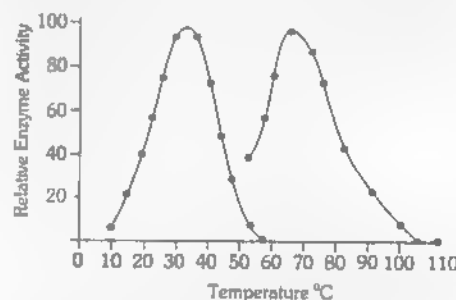
(a) 20 types of monomers (b) 40 types of monomers  
(c) 3 types of monomers (d) only one type of monomer

10. Proteins perform many physiological functions. For example, some functions as enzymes. One of the following represents an additional function that some proteins discharge [NCERT]

(a) Antibiotics  
(b) Pigment conferring colour to skin  
(c) Pigments making colours of flowers  
(d) Hormones

11. Glycogen is a homopolymer made of [NCERT]  
 (a) Glucose units (b) Galactose units  
 (c) Ribose units (d) Amino acids
12. The number of 'ends' in a glycogen molecule would be [NCERT]  
 (a) Equal to the number of branches plus one  
 (b) Equal to the number of branch points  
 (c) One  
 (d) Two, one on the left side and another on the right side
13. A pure protein should normally have [NCERT]  
 (a) Two ends (b) One end  
 (c) Three ends (d) No ends
14. Enzymes are biocatalysts. They catalyse biochemical reactions. In general they reduce activation energy of reactions. Many physico-chemical processes are enzyme mediated. Some examples of enzyme mediated reactions are given below. Tick the wrong entry [NCERT]  
 (a) Dissolving  $\text{CO}_2$  in water  
 (b) Unwinding the two strands of DNA  
 (c) Hydrolysis of sucrose  
 (d) Formation of peptide bond
3. Enzymes generally have  
 (a) Same pH and temperature optima  
 (b) Same pH but different temperature optima  
 (c) Different pH but same temperature optima  
 (d) Different pH and different temperature optima
4. Most of the biochemical reactions differ from those occurring in the non-living world in  
 (a) Requiring energy (b) Releasing energy  
 (c) Being enzymatic (d) Being spontaneous
5. A phosphoglyceride is always made up of [NEET 2013]  
 (a) A saturated or unsaturated fatty acid esterified to a phosphate group which is also attached to a glycerol molecule  
 (b) Only a saturated fatty acid esterified to a glycerol molecule to which a phosphate group is also attached  
 (c) Only a unsaturated fatty acid esterified to a glycerol molecule to which a phosphate group is also attached  
 (d) A saturated or unsaturated fatty acid esterified to a glycerol molecule to which a phosphate group is also attached

6. The given graph depicts the effect of temperature on the activity of the two enzymes A and B that catalyze the same reaction. Select the correct statement (s) for these results



- A. The rate of reaction in each case increases with increase in temperature and declines at higher temperatures due to denaturation of the enzyme
- B. Both the enzymes A and B are thermolabile
- C. At higher temperature the reactants become highly energized and fail to interact with active site, thus decreasing the rate of reaction
- D. The enzyme A is from a mesophilic organism, whereas the enzyme B is from a thermophilic organism [NCERT]
- (a) A, B, D (b) C and D  
 (c) B and C (d) A and B
7. In the modern system of nomenclature which one of the following enzyme occupies 6th position  
 (a) Ligase (b) Isomerase  
 (c) Lyase (d) Hydrolase
8. The most important property of an enzyme is its  
 (a) Composition (b) Thermal denaturation  
 (c) Specificity (d) Solubility
9. The ratio of the enzyme to substrate molecule can be as high as  
 (a) 1 : 1000 (b) 1 : 1,00,000  
 (c) 1 : 10,00,000 (d) 1 : 50,000
10. Repressible enzymes are formed [DPMT 2006]  
 (a) In the absence of corepressor  
 (b) In the presence of corepressor  
 (c) In the presence of apressor  
 (d) All of the above

## Critical Thinking

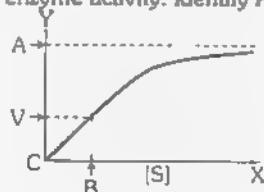
### Objective Questions

1. Which one out of A-D given below correctly represents the structural formula of the basic amino acid

[NCERT; CBSE PMT (Pre.) 2012]

A	B	C	D
$\begin{array}{c} \text{NH}_2 \\   \\ \text{H}-\text{C}-\text{COOH} \\   \\ \text{CH}_2 \\   \\ \text{CH}_3 \\   \\ \text{C}=\text{O} \\   \\ \text{OH} \end{array}$	$\begin{array}{c} \text{NH}_2 \\   \\ \text{H}-\text{C}-\text{COOH} \\   \\ \text{CH}_2 \\   \\ \text{OH} \end{array}$	$\begin{array}{c} \text{CH}_2\text{OH} \\   \\ \text{CH}_2 \\   \\ \text{CH}_2 \\   \\ \text{NH}_2 \end{array}$	$\begin{array}{c} \text{NH}_2 \\   \\ \text{H}-\text{C}-\text{COOH} \\   \\ \text{CH}_2 \\   \\ \text{CH}_2 \\   \\ \text{CH}_2 \\   \\ \text{CH}_2 \\   \\ \text{NH}_2 \end{array}$

- (a) C (b) D  
 (c) A (d) B
2. The given adjacent graph depicts the change in conc. of substrate on enzyme activity. Identify A, B and C [NCERT]



	A	B	C
(a)	$K_m$	$V_{max}$	$\frac{V_{max}}{2}$
(b)	$V_{max}$	$K_m$	$\frac{V_{max}}{2}$
(c)	$\frac{V_{max}}{2}$	$K_m$	$K_i$
(d)	$K_i$	$K_m$	$V_{max}$

11. The enzyme nitrogenase is extremely sensitive to  
[WB JEE 2016]

(a) Oxygen (b) Nitrogen  
(c) Hydrogen (d) Helium

12. Which of the following are not polymeric [NEET 2017]

(a) Nucleic acids (b) Proteins  
(c) Polysaccharides (d) Lipids

## R Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

- (a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion  
(b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion  
(c) If the assertion is true but the reason is false  
(d) If both the assertion and reason are false  
(e) If the assertion is false but reason is true

- Assertion : DNA is associated with proteins.  
Reason : DNA binds around histone proteins that form a pool and the entire structure is called a nucleosome. [AIIMS 2000]
- Assertion : The bonds attaching second and third phosphates in higher nucleotide are high energy bonds.  
Reason : The bonds are attached against force of repulsion.
- Assertion : Enzymes have active sites and substrates reactive sites, on their surfaces respectively.  
Reason : Active and reactive sites push the enzyme and substrate molecules away from each other. [AIIMS 1999]
- Assertion : Enzyme substrate complex remains throughout the reaction.  
Reason : The greater the affinity of the enzyme for a substrate, the higher is the catalytic activity.
- Assertion : Desmolysing enzymes are those which catalyse the reactions by hydrolysis.  
Reason : Digestive enzymes are hydrolysing in nature.
- Assertion : Coenzymes are also called prosthetic groups  
Reason : Coenzymes and prosthetic groups are cofactors.
- Assertion : Enzymes are defined as biological proteins.  
Reason : Chemically all enzymes are globular proteins. [AIIMS 1997]
- Assertion : DNA molecules and RNA molecules are found in the nucleus of cell.  
Reason : On heating, enzymes do not lose their specific activity. [AIIMS 1994]

- Assertion : The higher the turn-over number the more efficient an enzyme is.  
Reason : It is not dependent upon the number of active sites present over an enzyme.
- Assertion : Allosteric enzymes show feed back inhibition.  
Reason : The inhibitor is competitive.
- Assertion : Enzyme becomes inactive below minimum temperature.  
Reason : The inactivity of the enzymes is due to denaturation.
- Assertion : Enzymes lower the activation energy.  
Reason : A substrate molecule can be acted upon by a particular enzyme. [AIIMS 2011]

## Answers

### Carbohydrates, Starch and Protein

1	a	2	a	3	c	4	d	5	c
6	b	7	b	8	a	9	d	10	b
11	a	12	d	13	a	14	d	15	a
16	c	17	d	18	d	19	b	20	b
21	c	22	e	23	c	24	d	25	d
26	a	27	a	28	a	29	d	30	b
31	d	32	a	33	d	34	a	35	c,d
36	b	37	a	38	a	39	a	40	a
41	a	42	a	43	a	44	d	45	b
46	c	47	a	48	c	49	b	50	a
51	c	52	d	53	a	54	e	55	a
56	d	57	d	58	b	59	a	60	abc

### Nucleotides and Nucleic acid

1	d	2	d	3	c	4	d	5	a
6	c	7	c	8	c	9	c	10	d
11	d	12	a	13	d	14	d	15	c
16	d	17	a	18	a	19	a	20	d
21	b	22	b	23	c	24	c	25	b
26	d	27	c	28	a	29	c	30	a
31	d								

### Introduction, properties, action and Inhibition of enzyme

1	b	2	d	3	b	4	b	5	a
6	a	7	a	8	b	9	a	10	b
11	c	12	c	13	c	14	c	15	c
16	c	17	c	18	b	19	d	20	c
21	b	22	b	23	b	24	c	25	a
26	d	27	c	28	c	29	c	30	d
31	c	32	d	33	c	34	a	35	b
36	c	37	b	38	b	39	b	40	b
41	c	42	b	43	b	44	c	45	a
46	a	47	d	48	e	49	d	50	d
51	c	52	b	53	d	54	c	55	a
56	c								

### Classification and factors affecting enzyme

1	d	2	b	3	c	4	a	5	b
6	c	7	c	8	a	9	d	10	b
11	c	12	d	13	a	14	a	15	b
16	b	17	a	18	c	19	b	20	d
21	b	22	c	23	b	24	c	25	c
26	a	27	c	28	b	29	c	30	b
31	c								

### NCERT Exemplar Questions

1	c	2	a	3	b	4	d	5	a
6	d	7	a	8	b	9	a	10	d
11	a	12	a	13	a	14	d		

### Critical Thinking Questions

1	b	2	b	3	c	4	c	5	d
6	a	7	a	8	c	9	c	10	a
11	a	12	d						

### Assertion and Reason

1	a	2	a	3	c	4	e	5	e
6	a	7	a	8	d	9	c	10	c
11	c	12	b						

## Answers and Solutions

### Carbohydrates, Starch and Protein

- (a) Simple sugar i.e., monosaccharide. These are the simplest carbohydrates and are building units of complex carbohydrates. i.e., Starch and cellulose.
- (a) Fructose is the most common form of sugar. It is the sweetest among naturally occurring sugars. It has sweetening index of 170 (where as the sweetening index of glucose is 70).
- (c) Inulin is homopolysaccharides, which is found in the root of dahlia plant.
- (b) Pentoses and hexoses are the example of monosaccharides.
- (b) Due to heating effect, disaccharides are dissociated into monosaccharides, which are sweet in nature.
- (a) Sucrose is the common cane or table sugar which is composed of D-glucose and fructose attached together by the aldehyde and ketone carbon.
- (d) The carbohydrates or sugar where free aldehyde or ketonic group is absent (utilized in glycosidic bond formation) can not reduce the above reagents are called non-reducing sugar i.e., Sucrose, glycogen, starch.
- (d) Dextran is a complex polysaccharide prepared either through partial hydrolysis of starch or polymerization of sucrose by the bacterium *Leuconostoc mesenteroides*.
- (d) The non proteinaceous prosthetic group is FMN or FAD. The protein is flavoprotein, which is a type of conjugated protein.
- (d) When protein adjoins with carbohydrates, is known as glycoprotein, which is a conjugated protein.
- (c) No cell could live without protein because proteins are building block of the body.
- (a) Lysine is an essential amino acid found in wheat. Which is not synthesized in the human body.
- (a) The union makes sucrose more stable than other sugars because both its anomeric carbon atoms are protected from oxidative attack. It is because of this reason, sucrose is used for transporting carbohydrates in plants.
- (b) Disaccharides composed of two unit of monosaccharides e.g. sucrose, maltose and lactose etc. Starch is the most common storage polysaccharide in plants.
- (a) Peptone is a derived protein. Others are conjugated proteins
- (c) The fatty acids having more than one double bond are called polyunsaturated fatty acids. Fats having such fatty acids are termed polyunsaturated fats. The latter are commended by physicians for persons having cardiovascular disease as their use lowers the blood cholesterol level.
- (b) Polymer of N-acetylglucosamine ( $C_8H_{13}O_5N$ )<sub>n</sub> that forms exoskeleton of arthropods and cell wall of fungi.
- (a) Ester bonds are formed in nucleic acids and lipids, but not proteins

## Nucleotides and Nucleic acid

12. (a) There is double hydrogen bond between adenine and thymine ( $A = T$ ) and triple bond between cytosine and guanine ( $C \equiv G$ ).
16. (d) Because plant viruses have RNA as genetic material.
17. (a) The two strands of DNA molecules run in opposite or antiparallel direction due to presence of hydrogen bond because two base i.e. one in each chain of DNA molecule, joined together by hydrogen bonds.
21. (b) Adenine and thymine; because C always attaches with G and A attaches with T.
25. (b) RNA is present both inside and outside the nucleus.

## Introduction, properties, action and inhibition of enzyme

1. (b) The term enzyme was used by Willy Kuhne while working on fermentation.
2. (d) Zymase is complex of enzyme. It obtained from yeast cell by Edward Buchner.
3. (b) All enzymes are proteins but all proteins are not enzyme.
5. (a) Arber and Nathans got nobel prize in 1978 for the discovery of restriction endonucleases.
6. (a) **Lock and key theory** : Emil Fischer proposed this theory, according to which on the surface of enzymes a few elevations and ditches are found known as active sites and enzymes bind reactants on these sites to create reaction between them.
9. (a) First time fermentative enzymes were discovered from yeast.
15. (c) Because enzymes are made up of proteins which are basically polymers of amino acids.
17. (c) In competitive inhibition,  $K_m$  value increases
19. (d) Viruses are acellular organisms.
24. (c)  $K_m$  is a Michaelis Menten constant, which indicates the substrate concentration at which the chemical reaction catalysed by an enzyme attains half its maximum velocity.
26. (d) Inhibition of succinic dehydrogenase by malonate is an example of competitive inhibition. This is reversible reaction. On increasing the substrate (succinate) concentration the effect of inhibitor is removed and  $V_{max}$  remain same.
29. (c) Enzymes used as biological detergents

Application	Enzyme used	Uses
Biological detergents	Primarily Proteases, Produced in an extracellular form by bacteria.	Used for the pre-soak or main wash, break down protein stains on clothes; also used in dishwashers to remove food residues.
	Amylases	Remove starch stains from clothes; also used in dishwashers to remove resistant starch residues.
	Cellulase	Softens and brightens colour of cotton fabrics.

30. (d) Most enzymes are proteins but some are lipids.
33. (c) Coenzymes are loosely attached complex non-protein, low molecular weight, thermostable, organic or metallo-organic groups. Which readily separate from the apoenzyme.
34. (a) In each and every molecule energy of activation is found, in which a few have more while others have less energy. Enzymes facilitates in between two molecules lowering their energy of activation.
35. (b) The proteinaceous part of an enzyme is called apoenzyme. The apoenzyme plus non proteinaceous part is called holoenzyme.
38. (b) One is active site and second is allosteric site.
41. (c) Permeases are found in the plasma membrane of the cell. Which take part in transportation of ions etc.
47. (d) Flavin mononucleotide (FMN), Flavin adenine dinucleotide (FAD) contains riboflavin (vitamin  $B_2$ ).
49. (d) Co-enzymes are organic molecules which acts as co-factors, but unlike prosthetic groups they do not remain attached to the enzyme between reaction. NAD, NADP and FAD are co-enzymes whereas ATP is an energy carrier in cell.
53. (d) The best evidence of lock and key theory or template theory of enzyme action comes from the observation that compounds similar in structure to the substrate inhibit the reaction.
54. (c) The substance which causes change in allosteric sites are known as modulators. They are of two types activator and inhibitor. Hexokinase is the example of inhibitor modulator

## Classification and factors affecting enzyme

7. (c) **Zymogens** : These are inactive enzyme precursors which in need can be convert in enzymes
9. (d) Amylase digest the stored food material of germinated cotton seed.
15. (b) Activation energy is required for overcoming the energy barrier which gets reduced in the presence of enzyme.
17. (a) **Isoenzymes** : A few enzymes are isomerically equal to others and are only differing in their molecular structure.
25. (c) 
$$C_6H_{12}O_6 \xrightarrow[\text{Glucose}]{\text{Yeast/Zymase}} C_2H_5OH + 2CO_2$$
 Alcohol
27. (c) X-axis represent temperature and Y-axis represent enzyme activity. All enzymes act at an optimum temperature, above and below this temperature the enzyme activity declines.
30. (b) If temperature increases from  $3^\circ C$  to  $45^\circ C$ , firstly it reaches to optimum condition and later temperature conditions are not optimum for enzyme activity. Thus the rate of enzyme activity initially increases and then decreases.



## Critical Thinking Questions

3. (c) Each enzyme has its own different favourable *pH* value but same temperature optima.
4. (c) Biochemical reactions of living beings are different from non-living world because in non-living beings, catalysts of reactions are mostly inorganic metals.
8. (c) Because a particular enzyme can catalyse only a particular type of reaction.
9. (c) Enzymes show reversible reactions and act by lowering energy of activation by more than 50%. They work in milliseconds and rate of enzyme to substrate is as high as 1.1000000
10. (a) Some enzymes are normally present in cell but their synthesis is ceased when the concentration of their end product become high, such enzymes are called **repressible enzymes** whereas the end product is called **corepressor**.

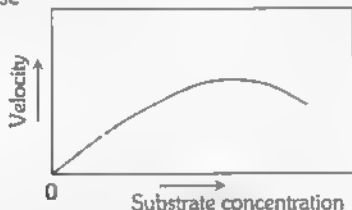
A regulator gene produces the aporepressor which unites with corepressor to form a functional repressor molecule. This repressor molecule inhibit mRNA synthesis by all genes specifying **enzymes**.

## Assertion and Reason

1. (a) A chain of DNA has 140 base pairs, make  $1\frac{3}{4}$  turns and twist around a histone octamer forming nucleosome. The core of nucleosome consists of 4 histones  $H_2A, H_2B, H_3$  and  $H_4$ .
2. (a) Nucleotides having more than one phosphate group are called higher nucleotides. The second and third phosphates of higher nucleotides are attached against forces of repulsion between similarly charged phosphate radicals. Hence, the bonds attaching second and third phosphates are higher energy bonds.
3. (c) Enzyme has specific site for substrates called as active sites and substrate has reactive sites. These active and reactive sites help in making of substrates enzyme complex.
4. (e) The enzymes substrate complex is short lived. The substrate is changed into products. The products remain complexed with the active site of the enzyme for a brief period. They soon separate and the active site is free to perform another catalytic act. Enzymes activity depends upon their affinity of substrates. If turnover number of substrate is higher, then enzymes show high affinity towards substrate. The number of substrate molecules changed per minute by a molecule or enzyme is called turn over number.
5. (e) Desmolysing enzymes are those which catalyse reactions by the other methods other than hydrolysis, e.g., aldolases, dehydrogenases, oxidases, etc. Digestive enzymes function by catalysing hydrolysis. Larger molecules are broken into smaller ones. They are grouped into three types – proteolytic (breaks protein molecule), amylolytic (breaks sugar molecule) and lipolytic (breaks lipid molecule).
6. (e) Cofactor may be inorganic or organic in nature. Organic cofactors are of two types, coenzymes and prosthetic groups. Coenzymes are easily separable nonprotein organic cofactors. Prosthetic groups are nonprotein organic cofactors firmly attached to apoenzymes (protein part of enzyme).
7. (a) We know that all biological reactions are catalysed by special catalysts called enzyme, thus enzymes are defined as biological proteins. We also know that enzymes are small organic molecules which are weakly held to the protein and can be easily separated by dialysis. Therefore chemically all enzymes are globular proteins.
8. (d) We know that DNA molecules are found primarily in the nucleus of the cell but RNA molecules are found outside the nucleus. By heating, its special structural arrangement is changed irreversibly, this result in the conversion of enzyme into a fibrous or insoluble form. Due to this irreversible change, enzymes lose their specific activity when heated.
9. (c) The number of substrate molecules changed per minute by a molecule or enzyme is called turn over number. The higher the turn-over number, the more efficient an enzyme is. It depends upon the number of active sites present over an enzyme.
10. (c) Feed back inhibition is a type of reversible inhibition found in allosteric enzymes. The inhibitor is noncompetitive and is usually a low molecular intermediate or product of metabolic pathway having a chain of reactions involving a number of enzymes.
11. (c) Enzyme becomes inactive below minimum temperature. Low temperature preserves the enzymes in the inactive state. High temperature destroys enzymes by causing their denaturation.
12. (b) Activation energy is an external supply of energy which is needed for the initiation of the chemical reaction. Activation energy required for such a large number of reactions cannot be provided by living systems. Enzymes lower the activation energy required for a reaction. Enzymes are generally specific for their substrates.

## Biomolecules

## Self Evaluation Test

- Raphides are found in [BHU 1995]
  - Dahlia
  - Asparagus
  - Nut
  - Guava
- Which level of protein structure is affected by DNA
  - Primary structure
  - Secondary structure
  - Tertiary structure
  - Quaternary structure
- Insoluble carbohydrate inulin is commonly found in [Odisha JEE 2009]
  - Root of beet
  - Stem of sugarcane
  - Fruit of grapes
  - Roots of Dahlia
- Ribose is a [MP PMT 2011]
  - Monosaccharide
  - Disaccharide
  - Polysaccharide
  - None
- The unit of cellulose is [MP PMT 2011]
  - Glucose
  - Fructose
  - Mannose
  - Galactose
- Which is true about enzymes
  - Lower the energy of activation of a reaction
  - Make the equilibrium more favourable for the organism
  - Lower the energy of product and increases the energy of reactant
  - Are altered permanently in the reaction they catalyse
- Papain produced from [Odisha JEE 2009]
  - Carica papaya*
  - Glycine max*
  - Citrus sp*
  - Ficus carica*
- What enzymes do for a biochemical reaction
  - Alter its rate
  - Alter its pattern
  - Alter both
  - None of the above
- The enzymes required to obtain protoplasts are [AMU (Med.) 2006; Odisha JEE 2008]
  - Cellulase and proteinase
  - Cellulase and amylase
  - Cellulase and pectinase
  - Amylase and pectinase
- Enzymes have a very narrow optima for
  - Light
  - Temperature
  - pH
  - Humidity
- The given graph shows the effect of substrate concentration on the rate of reaction of the enzyme green gram-phosphatase
 
- Molecular weight of enzyme is
  - Less than 5000
  - 5000 to 10000
  - 10000 to 20000
  - More than 40000
- The term 'feedback' refers to
  - The effect of end product on the rate of enzymatic reaction
  - The effect of substrate on the rate of enzymatic reaction
  - The effect of an external compound on the rate of enzymatic reaction
  - The effect of enzyme concentration on its rate of reaction
- Pepsin is inactivated at pH [BHU 2003]
  - Below 3
  - Below 2
  - Above 5
  - Above 3

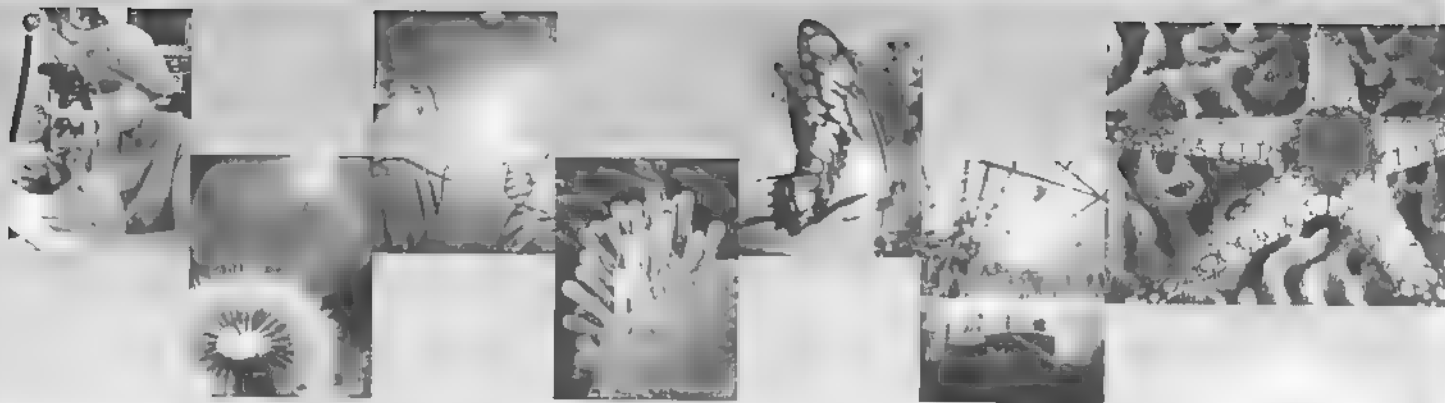
## Answers and Solutions

1	b	2	a	3	d	4	a	5	a
6	a	7	a	8	a	9	c	10	c
11	b	12	d	13	a	14	c		

- (b) Raphides are needle shaped structures of calcium oxalate. These are found in epidermal cells of *Asparagus*, *Eichhornia*, *Lemna* etc. Cell with raphides are called idioblasts.
- (d) Inulin is called 'Dahlia starch' and found in roots.
- (a) Enzyme act by decreasing the activation energy so that the number of activated molecules is increased at lower energy level.
- (c) Each enzyme operates within a narrow range of pH. It is most effective at a particular point of this range which is called optimum pH.
- (d) Peroxidase one of the smaller enzymes has molecular weight of 4,000, where as catalase one of the largest has a molecular weight of 250,000.
- (c) All enzymes are temperature and pH specific in nature pepsin of gastric juice works well at pH2.

What does the graph indicate [AIIMS 2005, 08]

- The rate of enzyme reaction is directly proportional to the substrate concentration
- Presence of an enzyme inhibitor in the reaction mixture
- Formation of an enzyme-substrate complex
- At higher substrate concentration the pH increase



## Chapter 3.3

# Cell Cycle and Cell Division

### Cell division / Cell reproduction / Cell cycle

It is the process by which a mature cell divides and forms two nearly equal daughter cells which resemble the parental cell in a number of characters.

In unicellular organisms, cell division is the means of reproduction by which the mother cell produces two or more new cells. In multicellular organism also, new individual develop from a single cell. Cell division is central to life of all cell and is essential for the perpetuation of the species.

**Discovery :** Prevost and Dumans (1824) first to study cell division during the cleavage of zygote of frog. Nageli (1846) first to propose that new cells are formed by the division of pre-existing cells.

Rudolf Virchow (1859) proposed "omnis cellula e cellula" and "cell lineage theory".

A cell divides when it has grown to a certain maximum size which disturb the karyoplasmic index (KI)/Nucleoplasmic ratio (NP)/Kernplasm connection.

**Cell cycle :** Howard and Pelc (1953) first time described it. The sequence of events which occur during cell growth and cell division are collectively called cell cycle. Cell cycle completes in two steps.

(1) Interphase, (2) M-phase/Dividing phase

(1) **Interphase :** It is the period between the end of one cell division to the beginning of next cell division. It is also called resting phase or not dividing phase. But, it is actually highly metabolically active phase, in which cell prepares itself for next cell division. In case of human beings it will take approx 25 hours. Interphase is completed into three successive stages.

**G<sub>1</sub> phase/Post mitotic/Pre-DNA synthetic phase/gap I<sup>st</sup>**

In which following events take place.

- (i) Intensive cellular synthesis.
- (ii) Synthesis of rRNA, mRNA ribosomes and proteins.
- (iii) Metabolic rate is high.
- (iv) Cells become differentiated.
- (v) Synthesis of enzymes and ATP storage
- (vi) Cell size increases.
- (vii) Decision for a division in a cell occurs.
- (viii) Substances of G stimulates the onset of next S – phase.

(ix) Synthesis of NHC protein, carbohydrates, proteins, lipids.

(x) Synthesis of enzyme, amino acids, nucleotides etc. but there is no change in DNA amount.

**S-phase/Synthetic phase**

(i) DNA replicates and its amount becomes double (2C - 4C).

(ii) Synthesis of histone proteins and NHC (non-histone chromosomal proteins).

(iii) Euchromatin replicates earlier than heterochromatin.

**G<sub>2</sub>-phase/Pre mitotic/Post synthetic phase/gap-II<sup>nd</sup>**

(i) Mitotic spindle protein (tubulin) synthesis begins.

(ii) Chromosome condensation factor appears.

(iii) Synthesis of 3 types of RNA, NHC proteins, and ATP molecule.

(iv) Duplication of mitochondria, plastids and other cellular macromolecular complements.

(v) Damaged DNA repair occur.

(2) **M-phase/Dividing phase/Mitotic phase :** It is divided into two phases, karyokinesis and cytokinesis.

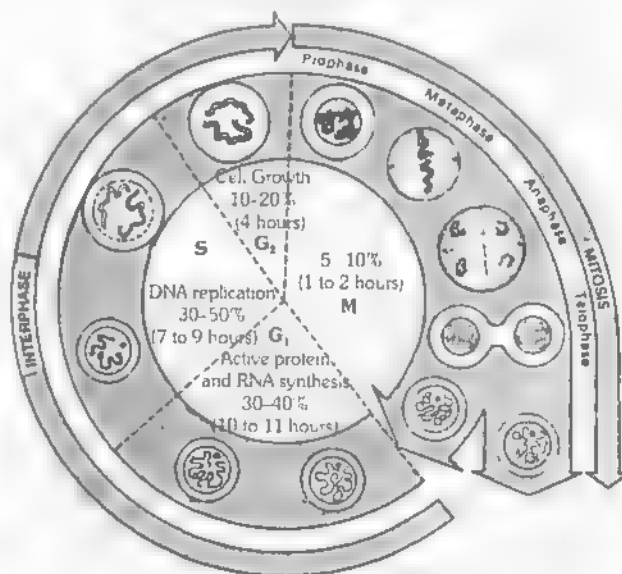


Fig : 3.3-1 Different stages of cell cycle (Mitotic cycle)

**Duration of cell cycle :** Time period for  $G_1$ , S,  $G_2$  and M-phase is species specific under specific environmental conditions. e.g., 20 minutes for bacterial cell, 8-10 hours for intestinal epithelial cell, and onion root tip cells may take 20 hours.

**$G_0$  – phase (Lajtha, 1963) :** The cells, which are not to divide further, do not proceed beyond the  $G_1$  phase and start undergoing differentiation into specific type. Such cells are said to be in  $G_0$  phase.

**Types of cell division :** It is of three types, Amitosis, Mitosis and Meiosis.

### Amitosis

Amitosis (Gk. *Amitos* = without thread; *osis* = state). It is also called as direct cell division. It was discovered by Remak (1855) in RBC of chick embryo. In this division there is no differentiation of chromosomes and spindle. The nuclear envelope does not degenerate. The nucleus elongates and constricts in the middle to form two daughter nuclei. This is followed by a centripetal constriction of the cytoplasm to form two daughter cells. It is primitive type of division occurring in prokaryotes, protozoans, yeasts, foetal membrane of mammals, cartilage of mammals etc.

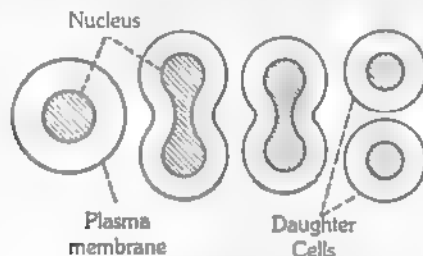


Fig : 3.3-2 Amitosis division

### Mitosis

Mitosis (Gk. *Mitos* = thread; *osis* = state). It is also called indirect cell division or somatic cell division or equational division. In this, mature somatic cell divides in such a way that chromosomes number is kept constant in daughter cells equal to those in parent cell. So it is called equational division.

**Discovery :** Mitosis was first observed by Strasburger (1875) in plant cell and in animal cell by W Flemming (1879). Term mitosis was given by Flemming (1882).

**Occurrence :** Mitosis is the common method of cell division. It takes place in the somatic cells in the animals and plants. Hence, it is also known as the somatic division. In plants mitosis occurs in the meristematic cells e.g., root apex and shoot apex.

**Process of mitosis :** Mitosis is completed in two steps.

**Karyokinesis :** (Gk. *Karyon* = nucleus; *kinesis* = movement) Division of nucleus. Term given by Schneider (1887). Karyokinesis it takes 5-10% (shortest phase) time of whole division. It comprises four phases i.e., Prophase, Metaphase, Anaphase, Telophase.

(1) **Prophase :** It is longest phase of karyokinesis.

(i) Chromatin fibres thicken and shorten to form chromosomes which may overlap each other and appears like a ball of wool, i.e., Spireme stage.

(ii) Each chromosome divides longitudinally into 2 chromatids which remain attached to centromere.

(iii) Nuclear membrane starts disintegrating except in dinoflagellates.

(iv) Nucleolus starts disintegrating.

(v) Cells become viscous, refractive and oval in outline.

(vi) Spindle formation begins.

(vii) Cell cytoskeleton, golgi complex, ER, etc. disappear.

(viii) In animal cells, centrioles move towards opposite sides.

(ix) Lampbrush chromosomes can be studied well

(x) Small globular structure (beaded) on the chromosome are called chromomeres.

(xi) Spindle is formed from centriole (in animal cells) or MTOC (microtubule organising centre) in plant cells successively called astral and anastral spindle.

(2) **Metaphase**

(i) Chromosomes become maximally distinct i.e., size can be measured.

(ii) A colourless, fibrous, bipolar spindle appears.

(iii) Spindle fibre are made up of 97% tubulin protein and 3% RNA.

(iv) Chromosomes move towards equatorial plane of spindles called congression and become arranged with their arms directed towards pole and centromere towards equator.

(v) Spindle fibres attach to kinetochores.

(vi) Metaphase is the best stage for studying chromosome morphology (structure, size, number).

(vii) Spindle has two type of fibres :

(a) Continuous fibre (run from pole to pole).

(b) Discontinuous fibre (between pole to centromeres).

(3) **Anaphase**

(i) Centromere splits from the middle and two chromatids gets separated.

(ii) Both the chromatids move towards opposite poles due to repulsive force called anaphasic movement.

(iii) Anaphasic movement is brought about by the repolymerisation of continuous fibres and depolymerisation of chromosomal fibres. Formation and expansion of interzonal fibres.

(iv) Different shape of chromosomes (V, J, I or L shapes) become evident during chromosome movement viz. metacentric acrocentric etc

(v) The centromere faces towards equator.

(vi) The chromatids are moved towards the pole at a speed of  $1 \mu\text{m}/\text{minute}$ . About 30 ATP molecules are used to move one chromosome from equator to pole.

(vii) Shape of chromosome is best studied at anaphase.

#### (4) Telophase

(i) Chromosomes reached on poles by the spindle fibers and form two groups.

(ii) Chromosomes begin to uncoil and form chromatin net.

(iii) The nuclear membrane and nucleolus reappear.

(iv) Two daughter nuclei are formed.

(v) Golgi complex and ER etc., reform.

(vi) This phase is also known as reverse prophase.

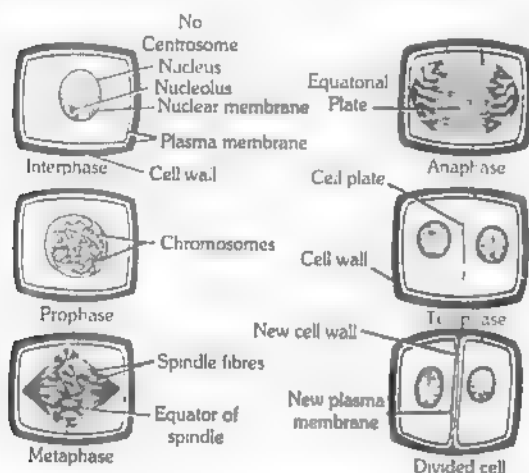


Fig : 3.3-3 Various stages of mitosis

**Cytokinesis** : (Gk -kitos = cell; kinesis = movement) Division of cytoplasm, Term given by Whiteman (1887). Division of cytoplasm into 2 equal parts.

Cytokinesis is by 2 methods :

(1) **Cell furrow method** : This is characteristic of animal cells. Due to absence of rigid cell wall here, the more flexible plasmamembrane forms the outer layer of cell. A **circular constriction** or invagination appears at centre or equator, which deepens gradually and finally two daughter cells are separated.

(2) **Cell plate method** : This is characteristic of plant cells. Here, vesicles provided by Golgi apparatus unite to form phragmoplasts, which join to form cell plate. Cell plate is first laid down in centre and then proceeds towards periphery (i.e., centrifugal plate-formation). Cell wall materials are now laid down on both sides of cell plate and thus forming two daughter cells.

#### Significance of mitosis

(1) It keeps the chromosome number constant and genetic stability in daughter cells, so the linear heredity of an organism is maintained. All the cells are with similar genetic constituents.

(2) It provides new cells for repair and regeneration of lost parts and healing of the wounds.

(3) It helps in asexual reproduction by fragmentation, budding, stem cutting, etc.

(4) Somatic variations when maintained by vegetative propagation can play important role in speciation.

#### Types of Mitosis

(1) **Intranuclear or Promitosis** : In this nuclear membrane is not lost and spindle is formed inside the nuclear membrane e.g., Protozoans (Amoeba) and yeast. It is so as centriole is present within the nucleus.

(2) **Extranuclear or Eumitosis** : In this nuclear membrane is lost and spindle is formed outside nuclear membrane e.g., in plants and animals.

(3) **Endomitosis** : Chromosomes and their DNA duplicate but fail to separate which lead to polyploidy e.g., in liver of man, both diploid (2N) and polyploid cells (4N) have been reported. It is also called endoduplication and endopolyploidy.

(4) **Dinomitosis** : In which nuclear envelope persists and microtubular spindle is not formed. During movement the chromosomes are attached with nuclear membrane.

**Mitotic poison** : The agents which inhibit cell division.

(1) **Azides and Cyanides** : Inhibit prophase.

(2) **Colchicine** : Inhibits spindle formation at metaphase.

(3) **Mustard gas** : Agglutinates the chromosomes.

(4) **Chalones** : These were first reported by Laurence and Bullough (1960). They are peptides and glycoproteins secreted by extracellular fluid of healthy cells and inhibit cellular division.

**Karyochoriosis** : A type of mitosis in fungi in which is intranuclear nucleus divides by furrow formation.

Table : 3.3-1

#### Difference between animal and plant cells (Mitosis)

Animal cells	Plant cells
Centrioles present at spindle poles.	Centrioles lacking at spindle poles.
Asters are formed (amphiasstral).	No asters are formed (anastral)
Cytokinesis by furrowing of cytoplasm.	Cytokinesis mostly by cell plate formation.
Furrow extends centripetally	Cell plate grows centrifugally

Microfilament ring brings about cleavage	Microfilaments have no role in cytokinesis
Occurs nearly in all tissues.	Occurs mainly at meristems.
Cell becomes rounded and its cytoplasm more viscous at the time of mitosis.	Cell does not change form or nature at the time of mitosis.
Midbody is formed at the equator of the spindle.	Equator of the spindle changes into phragmoplast.
Intercellular spaces appear between the daughter cells.	Daughter cells remain adhered together by middle lamella.
Animal mitosis is controlled by certain mitogens.	Plant mitosis is usually controlled by a hormone cytokinin

### Meiosis

**Meiosis** (Gr. *meio* – to lessen, *osis* – state). *Meiosis is a much slower process than mitosis.* It is a double division that occurs in a mature diploid reproductive cell ( $2x$ ) in which nucleus divides twice but chromosome (DNA) replicates only once to form four haploid cells, each having the half the number of chromosomes present in the parent cell. As it causes reduction in the number of chromosomes, it is known as **reduction division**. Meiosis in a cell occurs only once. The so formed haploid cells do not further undergo meiosis because there is no synaptonemal complex in haploid genome.

**Discovery** : It was first demonstrated by *Van Beneden* (1887) but was described by *Winiwarter* (1900). Term “meiosis” was given by *Farner and Moore* (1905). *Gregoire* used the term meiosis I and II.

**Occurrence** : It is found in special types and at specific period. It is reported in diploid germ cells of sex organs (e.g., primary spermatocytes of testes to form male gametes called spermatozoa and primary oocytes to form female gametes called ova in animals) and in pollen mother cells (microsporocytes) of anther and megasporocyte of ovule of ovary of flowers in plant to form the haploid spores. The study of meiosis in plants can be done in young flower buds.

**Process of meiosis** : Meiosis is completed in two steps, meiosis I and meiosis II

**Meiosis-I** : In which the actual chromosome number is reduced to half. Therefore, meiosis I is also known as reductional division or heterotypic division. It results in the formation of two haploid cells from one diploid cell. It is divided into two parts, karyokinesis I and cytokinesis I.

**Karyokinesis-I** : It involves division of nucleus. It is divided into four phases i.e., prophase, metaphase, anaphase, telophase.

1) **Prophase-I** : It is of longest phase of karyokinesis of meiosis. It is again divisible into five subphases i.e., leptotene, zygotene, pachytene, diplotene and diakinesis.

#### (i) Leptotene/Leptonema

- (a) Chromosomes are long thread like with chromomeres on it.
- (b) Volume of nucleus increases.
- (c) Chromatin network has half chromosomes from male and half from female parent.
- (d) Chromosome with similar structure are known as homologous chromosomes.
- (e) Leptonemal chromosomes have a definite polarization and forms loops whose ends are attached to the nuclear envelope at points near the centrioles, contained within an aster. Such peculiar arrangement is termed as *bouquet stage* (in animals) and *syndet knot* (in plants).

(g) Lampbrush chromosome found in oocyte of amphibians is seen in leptotene.

#### (ii) Zygotene/Zygonema

- (a) Pairing or “synapsis” of homologous chromosomes takes place in this stage.
- (b) Paired chromosomes are called bivalents, which by further molecular packing and spiralization becomes shorter and thicker.
- (c) Pairing of homologous chromosomes in a zipper-fashion. Number of bivalents (paired homologous chromosomes) is half to total number of chromosomes in a diploid cell. Each bivalent is formed of one paternal and one maternal chromosome (i.e., one chromosome derived from each parent).
- (d) Under EM, a filamentous ladder like nucleoproteinous complex, called synaptonemal. Synaptonemal complex is seen between the homologous chromosomes which was discovered by “*Moses*” (1956).

#### (iii) Pachytene/Pachynema

- (a) In the tetrad, two similar chromatids of the same chromosome are called sister chromatids and those of two homologous chromosomes are termed non-sister chromatids.
- (b) Crossing over i.e., exchange of segments between non-sister chromatids of homologous chromosome occurs at this stage.

It takes place by breakage and reunion of chromatid segments. Breakage called nicking, is assisted by an enzyme endonuclease and reunion termed annealing is added by an enzyme ligase. Breakage and reunion hypothesis proposed by *Darlington* (1937).

(c) Chromatids of pachytene chromosome are attached with centromere.

(d) A tetrad consists of two sets of homologous chromosomes each with two chromatids. Each tetrad has four kinetochores (two sister and two homologous).

(e) A number of electron dense bodies about 100 nm in diameter are seen at irregular intervals within the centre of the synaptonemal complex, known as recombination nodules.

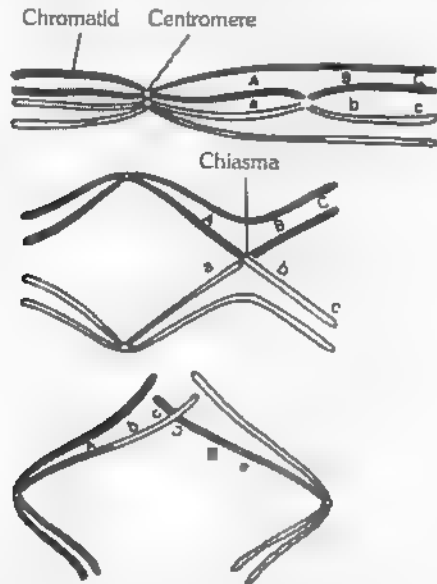


Fig : 3.3-4 Crossing over during meiosis

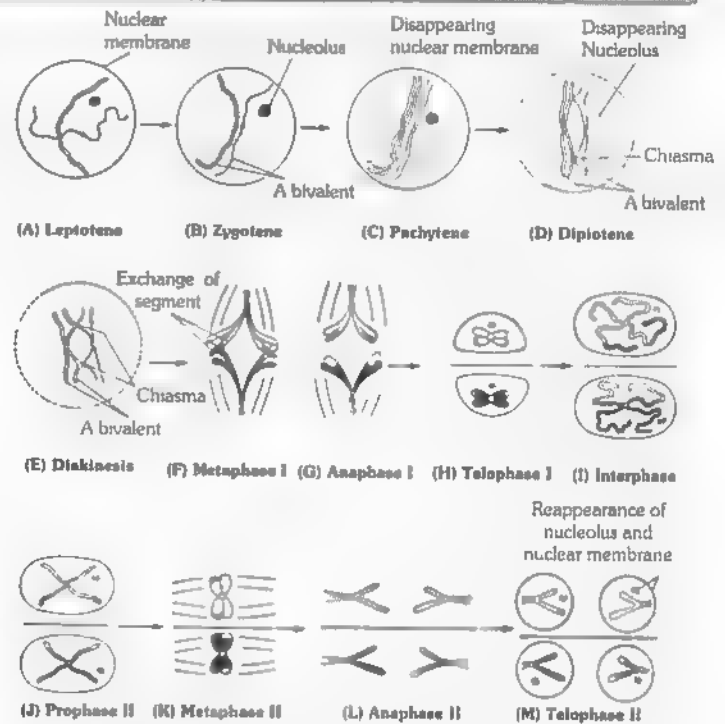


Fig : 3.3-5 Different stages of meiotic cell division (meiosis)

## (2) Metaphase-I

(i) Chromosome come on the equator.

(ii) Bivalents arrange themselves in two parallel equatorial or metaphase plates. Each equatorial plate has one genome.

(iii) Centromeres of homologous chromosomes lie equidistant from equator and are directed towards the poles while arms generally lie horizontally on the equator.

(iv) Each homologous chromosome has two kinetochores and both the kinetochores of a chromosome are joined to the chromosomal or tractile fibre of same side.

## (3) Anaphase-I

(i) It involves separation of homologous chromosomes which start moving opposite poles so each tetrad is divided into two daughter dyads. So anaphase-I involves the reduction of chromosome number, this is called *disjunction*.

(ii) The shape of separating chromosomes may be rod or J or V-shape depending upon the position of centromere.

(iii) Segregation of Mendelian factors or independent assortment of chromosomes take place. In which the paternal and maternal chromosomes of each homologous pair segregate during anaphase-I which introduces genetic variability.

## (4) Telophase-I

(i) Two daughter nuclei are formed but the chromosome number is half than the chromosome number of mother cell

(ii) Nuclear membrane reappears.

(iii) After telophase I cytokinesis may or may not occur.

(f) DNA polymerase is responsible for the repair synthesis.

## (iv) Diplotene/Diplonema

(a) At this stage the paired chromosomes begin to separate (desynapsis). Terminalisation starts.

(b) Cross is formed at the place of crossing over between non-sister chromatids.

(c) Homologous chromosomes move apart they remain attached to one another at specific points called chiasmata.

(d) At least one chiasma is formed in each bivalent.

(e) Chromosomes are attached only at the place of chiasmata.

(f) Chromatin bridges are formed in place of synaptonemal complex on chiasmata.

(g) This stage remains as such for long time.

## (v) Diakinesis

(a) Terminalization completes.

(b) Nuclear membrane and nucleolus degenerates.

(c) Chromosome recondense and tetrad moves to the metaphase plate.

(d) Formation of spindle.

(e) Bivalents are irregularly and freely scattered in the nucleocytoplasmic matrix.

When the diakinesis of prophase-I is completed than cell enters into the metaphase-I.

(iv) At the end of Meiosis I either two daughter cells will be formed or a cell may have two daughter nuclei.

(v) Meiosis I is also termed as reduction division.

(vi) After meiosis I, the cells in animals are reformed as secondary spermatocytes or secondary oocytes; with haploid number of chromosomes but diploid amount of DNA.

(vii) Chromosomes undergo decondensation by hydration and despiralization and change into long and thread like chromatin fibres.

**Interphase :** Generally there is no interphase between meiosis-I and meiosis-II. A brief interphase called interkinesis, or intrameiotic interphase. There is no replication chromosomes, during this interphase.

**Cytokinesis-I :** It may or may not be present. When present, it occurs by cell-furrow formation in animal cells and cell plate formation in plant cells.

#### Significance of meiosis-I

(1) It separates the homologous chromosomes to reduce the chromosome number to the haploid state, a necessity for sexual reproduction.

(2) It introduces variation by forming new gene combinations through crossing over and random assortment of paternal and maternal chromosomes.

(3) It induces the cells to produce gametes for sexual reproduction or spores for asexual reproduction.

**Meiosis-II :** It is also called equational or homotypical division because the number of chromosomes remains same as after meiosis-I. It is of shorter duration than even typical mitotic division. It is also divisible into two parts, Karyokinesis-II and Cytokinesis-II.

**Karyokinesis-II :** It involves the separation of two chromatids of each chromosome and their movement to separate cells. It is divided in four phases i.e., Prophase-II, Metaphase-II, Anaphase-II and Telophase-II.

Almost all the changes of Karyokinesis-II resembles to mitosis which involves.

(1) It starts just after end of telophase I.

(2) Each daughter cell (nucleus) undergoes mitotic division.

(3) It is exactly similar to mitosis.

(4) At the end of process, cytokinesis takes place.

(5) Four daughter cells are formed after completion.

(6) The sister kinetochores of one chromosome are separated.

(7) The four daughter cells receive one chromatid each of the tetraivalent.

(8) Centromere split at anaphase II.

(9) Spindle fibres contract at prophase II

**Cytokinesis-II :** It is always present and occurs by cell furrow formation in animal cell and cell plate formation in plant cell

So by meiosis, a diploid parental cell divides twice forming four haploid gametes or sex cells, each having half the DNA amount than that of the parental cell and one-fourth of DNA present in the cell at the time of beginning of meiosis.

#### Significance of meiosis-II

(1) Constancy of chromosome number in successive generation is brought by process.

(2) Chromosome number becomes half during meiosis.

(3) It helps in introducing variations and mutation.

(4) It brings about gamete formation.

(5) It maintains the amount of genetic informative material.

(6) Sexual reproduction includes one meiosis and fusion.

(7) The four daughter cells will have different types of chromatids.

#### Types of meiosis

(1) **Gametic/Terminal meiosis :** In many protozoans, all animals and some lower plants, meiosis takes place before fertilization during the formation of gametes. Such a meiosis is described as gametic or terminal.

(2) **Zygotic or Initial meiosis :** In fungi, certain protozoan groups, and some algae fertilization is immediately followed by meiosis in the zygote, and the resulting adult organisms are haploid. Such a meiosis is said to be zygotic or initial. This type of life cycle with haploid adult and zygotic meiosis is termed the haplontic cycle.

(3) **Sporogenetic / Intermediate meiosis**

(i) Diploid sporocytes or spore mother cells of sporophytic plant, undergo meiosis to form the haploid spores in the sporangia.

(ii) Haploid spore germinates to form haploid gametophyte which produces the haploid gametes by mitosis.

(iii) Haploid gametes fuse to form diploid zygote which develops into diploid sporophyte by mitotic divisions. e.g., In higher plants like pteridophytes, gymnosperms and angiosperms.

Table : 3.3-2

Where does meiosis take place in different plant

Plant	Stage at which meiosis occurs
<i>Chlamydomonas</i> (alga)	In zygote
<i>Ulothrix</i> (alga)	In zygospore
<i>Spirogyra</i> (alga)	In zygospore
<i>Rhizopus</i> or Bread mould (fungus)	In zygospore
<i>Saccharomyces</i> or Yeast (fungus)	During formation of ascospores in ascus mother cell or ascus
<i>Riccia</i> , <i>Marchantia</i> , <i>Funaria</i> , etc. (Bryophytes)	In spore mother cell inside capsule of sporophyte
Ferns (Pteridophytes)	In spore mother cell inside sporangium
Gymnosperms (e.g., <i>Cycas</i> , <i>Pinus</i> , etc.)	In microspore mother cells and megaspore mother cells inside
Angiosperms (Wheat, pea, etc.)	Microsporangia and megasporangia during formation of microspores (pollens) and megaspores.



Table : 3.3-3

## Differences between Mitosis and Meiosis

Mitosis	Meiosis
<p><b>General</b></p> <p>This division takes place in all kinds of cells and may continue throughout life</p> <p>Nucleus undergoes a single division at the completion of division cycle. Similar is the case with chromosomes</p> <p>Two daughter cells are formed at the end of mitosis</p> <p>The chromosome no. remains constant in daughter cells like parent cell, i.e., daughter cells are <b>genetically identical</b> to parent cell.</p> <p>Mitosis is much shorter.</p> <p>Mitosis may occur in diploid or haploid cells</p>	<p>It usually occurs in reproductive cells just before formation of gametes or spores in the life cycle of a plant</p> <p>Nucleus undergoes two divisions, first is reductional while second is equational, at the completion of division cycle, while the chromosomes divide only once, i.e., in anaphase II.</p> <p>Four daughter cells are formed at end.</p> <p>The chromosome no. is reduced to half in daughter cells as compared to parent cells, i.e., daughter cells are <b>genetically different</b> from parent cell.</p> <p>Meiosis is much longer</p> <p>Meiosis always occurs in diploid cells (meiocytes).</p>
<p><b>Prophase</b></p> <p>Prophase is short and is without sub-stages</p> <p>There is no pairing of homologous chromosomes (synapsis) and hence no chance of <b>crossing over</b> and <b>chiasmata formation</b>.</p> <p>No synaptonemal complex (SC) is formed between chromosomes.</p> <p>The chromosomes are longitudinally split into two sister chromatids during early prophase, i.e., prophase chromosomes appear double from the very beginning.</p> <p>Chromosomes do not unfold and there is <b>no transcription</b> and <b>protein synthesis</b> in prophase</p>	<p>Prophase I is prolonged with 5 different sub-stages as leptotene, zygotene, pachytene, diplotene and diakinesis</p> <p>Homologous chromosomes pair during <b>zygotene sub-stage</b> of prophase I and often <b>undergo crossing over</b> and hence <b>forming chiasmata</b>.</p> <p>Synaptonemal complex (tripartite protein framework) is formed between pairing homologous chromosomes</p> <p>The chromosomes are <b>not longitudinally split</b> but appear as single thread, i.e., prophase I chromosomes do not appear double in the beginning.</p> <p>Chromosomes unfold and there may occur transcription and protein synthesis during <b>diplotene</b> sub-stage of prophase I.</p>
<p><b>Metaphase</b></p> <p>All chromosomes form a single plate in metaphase.</p> <p>On equatorial plate, chromosomes appear two threaded.</p>	<p>Chromosomes form 2 parallel plates in metaphase I and one plate in metaphase II.</p> <p>On equatorial plate, chromosomes appear four threaded in metaphase I, while metaphase II is similar to metaphase of mitosis.</p>

**Anaphase**

Splitting of centromere of chromosomes and hence separation of 2 chromatids of each chromosome occurs at anaphase.

There is no splitting of centromeres in anaphase I and there is separation of homologous chromosomes in anaphase I. In anaphase II, splitting of centromeres and hence separation of chromatids occurs

**Telophase**

Telophase occurs in all cases.

In some cases, telophase I is omitted.

Daughter cells have same number of chromosomes as parent cell.

At the end of telophase I, chromosome number is reduced to half

**Cytokinesis**

**Karyokinesis** (division of nucleus) is usually followed by **cytokinesis** (wall formation)

Sometimes cytokinesis does not occur after telophase I or meiosis I but it **always occurs** after meiosis II or telophase II, thus forming 4 cells simultaneously.

**Significance**

Mitosis is responsible for growth, repair and healing

Meiosis is responsible for maintaining chromosomes number constant from generation to generation, forms gametes or spores and also produces variations due to crossing over.

## Tips & Tricks

- ✚ Interkinesis . Stage between meiosis I and meiosis II.
- ✚ Mitosis index is the ratio of dividing and non-dividing cells.
- ✚ Karyochoriosis : A type of mitosis in fungi in which is intranuclear nucleus divides by furrow formation.
- ✚ In mitosis, plectonemic coiling takes place, in which sister chromatids are tightly coiled upon each other and are not easily separable. Paranemic coiling found in meiosis.
- ✚ Brachymeiosis : Failure of meiosis-II. It is characteristic feature of fungi.
- ✚ Chiasmata first observed by Janssens (1909).
- ✚ To study mitosis root tips are fixed in 1: 3 acetic acid and methanol.
- ✚ Mitotic crossing over takes place in parasexual cycle.
- ✚ Cell cycle duration – 20 minutes in bacteria, 20 hours in root tip of onion. 2-3 hrs in yeast, 24- hrs man.



## Ordinary Thinking

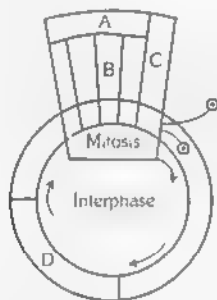
### Objective Questions

#### Cell division

- The term "meiosis" was coined by
  - Hertwig and Van Bevedin
  - Sutton and Boveri
  - Hofmeister and Waldeyer
  - Farmer and Moore
- Coiling of chromatids in mitotic and meiotic division is
 

[MP PMT 2002]

  - Paranemic in both
  - Plectonemic in both
  - Paranemic in mitosis and plectonemic in meiosis
  - Plectonemic in mitosis and paranemic in meiosis
- Given below is a schematic break-up of the phases/stages of cell cycle



Which one of the following is the correct indication of the stage/phase in the cell cycle [CBSE PMT 2009]

- B-Metaphase
  - C-Karyokinesis
  - D-Synthetic phase
  - A-Cytokinesis
- Condensation of chromosomes occurs in [AFMC 2002]
    - Prophase I
    - Prophase II
    - Anaphase
    - Metaphase
  - Find the correctly matched pairs and choose the correct option
 

A. Leptotene	–	The chromosomes become invisible
B. Zygotene	–	Pairing of homologous chromosomes
C. Pachytene	–	Dissolution of the synaptonemal complex takes place
D. Diplotene	–	Bivalent chromosomes appear as tetrads
E. Diakinesis	–	Terminalization of chiasmata takes place

[AFMC 1995; Odisha JEE 2012; Kerala PMT 2012]

    - A and B are correct
    - B and D are correct
    - B and E are correct
    - B and C are correct
    - C and D are correct
  - The role of meiosis [AFMC 2002]
    - Formation of gametes
    - Bringing haplophase
    - Bringing diplophase
    - Completing life cycle

- Which of the following events are not characteristic features of telophase
  - Chromosome material condenses to form compact mitotic chromosomes
  - Nucleolus, Golgi complex and ER reform
  - Nuclear envelope assembles around the chromosome clusters
  - Centromeres split and chromatids separate
  - Chromosomes cluster at opposite, spindle poles and their identity as discrete elements is lost

[Kerala PMT 2012]

- A, B and D only
  - A and D only
  - B and C only
  - C, D and E only
  - A and B only
- Which stage connecting link between Meiosis I and Meiosis II
 

[AFMC 2002; Kerala PMT 2011]

    - Interphase I
    - Interphase II
    - Interkinesis
    - Anaphase I
  - Which of the following stage is affected by colchicum
 

[BVP 2001; AFMC 2002; Pb. PMT 2004; Odisha JEE 2011]

Or

Spindle apparatus is formed during which stage of mitosis

[AFMC 1999]

- Metaphase
  - Prophase
  - Interphase
  - Anaphase
- "G<sub>0</sub>" state of cells in eukaryotic cell cycle denotes
 

[AIEEE Pharmacy 2003]

    - Check point before entering the next phase
    - Pausing in the middle of a cycle to cope with a temporary delay
    - Death of a cell
    - Exit of cells from cell cycle
  - Three copies of chromosome – 21 in a child with Down's syndrome have been formed analysed using molecular biology technology to detect any possible DNA polymorphism with reference to different alleles located on chromosome – 21. Results showed that out of 3 copies 2 of the chromosomes of the child contain the same alleles as one of the mother's alleles. Based on this when did the non-disjunction event most likely occur
 

[KCET 2015]

    - Paternal meiosis – I
    - Maternal meiosis – I
    - Paternal meiosis – II
    - Maternal meiosis – II
  - Mitosis occurs in [RPMT 2002]
    - Haploid individuals
    - Diploid individuals
    - Both (a) and (b)
    - In bacteria only
  - Which is not true for anaphase [Odisha JEE 2004]
    - Golgi body and ER are reformed
    - Chromosomes move to opposite poles
    - Spindle poles move farther apart
    - Centromeres split and chromatids separate
  - Cyclin is associated with which one of the following
 

[BHU 2000]

Or

Diploid living organism develops from zygote by repeated cell divisions is called [J & K C CET 2005]

- Glycolysis
- Cyclosis
- Haemolysis
- Mitosis

15. For viewing diakinesis which one of the following would be a suitable material [MP PMT 2002]  
(a) Onion root tip (b) Leaf of *Dichanthium*  
(c) Rat tail (d) Flower bud
16. Which is not the character of mitosis [MP PMT 2000]  
(a) Leptotene (b) Zygotene  
(c) Pachytene (d) All of the above
17. Synaptonemal complex is formed during [CBSE PMT 2001]  
(a) Meiosis (b) Amitosis  
(c) Mitosis (d) Cytokinesis
18. Synaptonemal complex was discovered in [BHU 2000]  
(a) 1956 (b) 1950  
(c) 1935 (d) 1980
19. Recombinant nodules are found during which of the following [BHU 2000]  
(a) Anaphase (b) Prophase  
(c) Telophase (d) Metaphase
20. Four daughter cells formed after meiosis are [MP PMT 2001]  
(a) Genetically similar (b) Genetically different  
(c) Anucleate (d) Multinucleate
21. The term synaptonemal complex refers to site of [BHU 2012]  
(a) Chromatid separation  
(b) Spindle attachment  
(c) Replication  
(d) Chromosome alignment and recombination
22. Repulsion of homologous chromosomes takes place in [MP PMT 2001]  
(a) Zygotene (b) Leptotene  
(c) Diakinesis (d) Diplotene
23. Which cell division is found during cleavage [RPMT 2001]  
(a) Amitosis (b) Mitosis  
(c) Closed mitosis (d) Meiosis
24. A stage in mitosis that starts towards the middle of anaphase and is completed with the telophase is [AFMC 2012]  
Or  
Division of cytoplasm after completion of nuclear division is called [MP PMT 2012]  
(a) Cytokinesis (b) Karyokinesis  
(c) Crossing over (d) Interkinesis
25. How many ATP is required during anaphase to move chromosomes from equator to the poles [BHU 2000]  
(a) 38 ATP (b) 5 ATP  
(c) 30 ATP (d) 76 ATP
26. Mitosis is the process by which eukaryotic cells [Pune CET 1998; CBSE PMT 2000; BHU 2000]  
(a) Expose the genes for protein synthesis  
(b) Become specialized in structure and function  
(c) Multiply  
(d) Grow
27. In pachytene stage of meiosis the chromosomes appear [MP PMT 1994; BHU 2002; Kerala PMT 2010]  
(a) Single stranded (b) Double stranded  
(c) Three stranded (d) Four stranded
28. Microtubule depolymerizing drug such as colchicine is expected to [AIIMS 2012]  
(a) Inhibit spindle formation during mitosis  
(b) Inhibit cytokinesis  
(c) Allow mitosis beyond metaphase  
(d) Induce formation of multiple contractile rings
29. Recombination of genes occur at [J & K CET 2002]  
(a) Prophase in mitosis (b) Prophase I in meiosis  
(c) Prophase II in meiosis (d) Metaphase II in meiosis
30. The second division in meiosis is called [KCET 1998]  
(a) Equational division (b) Reduction division  
(c) Multiplied division (d) None of the above
31. Which stages of cell division do the following figures A and B represent respectively [NCERT; CBSE PMT (Pre.) 2010]



A



B

- (a) Prophase – Anaphase  
(b) Metaphase – Telophase  
(c) Telophase – Metaphase  
(d) Late Anaphase – Prophase

32. Select correct option

	I		I
(A)	Synapsis aligns homologous chromosomes	(i)	Anaphase-II
(B)	Synthesis of RNA and protein	(ii)	Zygotene
(C)	Action of enzyme recombinase	(iii)	G <sub>2</sub> -phase
(D)	Centromeres do not separate but chromatids move towards opposite poles	(iv)	Anaphase-I
		(v)	Pachytene

[AIPMT (Cancelled) 2015]

	(A)	(B)	(C)	(D)
(a)	(ii)	(iii)	(v)	(iv)
(b)	(i)	(ii)	(v)	(iv)
(c)	(ii)	(iii)	(iv)	(v)
(d)	(ii)	(i)	(iii)	(iv)

33. Which of the following statements is incorrect about G<sub>0</sub> phase [AIIMS 2012]

- (a) Mitosis occurs after G<sub>0</sub> phase  
(b) Biocatalysts can be used to exit G<sub>0</sub> phase  
(c) Cell volume keeps on increasing during this phase  
(d) Cell metabolism occurs continuously in G<sub>0</sub> phase

34. A somatic cell that has just completed the S-phase of its cell cycle, as compared to gamete of the same species, has

[AIPMT (Cancelled) 2015]

- (a) Same number of chromosomes but twice the amount of DNA
- (b) Twice the number of chromosomes and four times the amount of DNA
- (c) Four times the number of chromosomes and twice the amount of DNA
- (d) Twice the number of chromosomes and twice the amount of DNA

35. Arrange the following events of meiosis in correct sequence

- (A) Crossing over
- (B) Synapsis
- (C) Terminalisation of chiasmata
- (D) Disappearance of nucleolus

[AIPMT 2015]

- (a) (B), (A), (C), (D)                      (b) (A), (B), (C), (D)
- (c) (B), (C), (D), (A)                      (d) (B), (A), (D), (C)

36. In Which stage of meiosis crossing over takes place

[Odisha JEE 2009]

- (a) Prophase - 1                      (b) Prophase
- (c) Metaphase                      (d) Anaphase

37. Beads on string like structures of A are seen in B, which further condense to form chromosomes in C stage of cell division. What are A, B and C

[AIIMS 2012]

	A	B	C
(a)	Chromonema	Chromatin	Metaphase
(b)	Chromatin	Chromatid	Metaphase
(c)	Chromonema	Chromosome	Anaphase
(d)	Chromonema	Chromatid	Anaphase

38. The best stage to count the number of chromosomes during mitosis is or structure of chromosomes can be best seen at

[CPMT 2000; BHU 2001; CBSE PMT 2004;

J & K CET 2008; MP PMT 2010]

Or

In which phase of mitosis the chromosomes are arranged around the equator of the spindle

[Manipal MEE 1995; CPMT 1998; Kerala CET 2002;

BVP 2002; RPMT 2005; MP PMT 2009]

- (a) Prophase                      (b) Metaphase
- (c) Anaphase                      (d) Telophase

39. In 'S' phase of the cell cycle

[CBSE PMT 2014]

- (a) Chromosome number is increased
- (b) Amount of DNA is reduced to half in each cell
- (c) Amount of DNA doubles in each cell
- (d) Amount of DNA remains same in each cell

40. Homologous pairing in prophase I of meiosis I is called

[MP PMT 2005]

- (a) Synapsis                      (b) Linkage
- (c) Crossing over                      (d) Syndesis

41. In meiosis, the centromere divides during

[MP PMT 1996, 97, 2001, 11; CBSE PMT 2000; BVP 2002]

- (a) Prophase-I                      (b) Metaphase-I
- (c) Anaphase-I                      (d) Anaphase-II

42. During interphase, RNA and proteins are synthesized in

[MP PMT 1997]

- (a) S phase
- (b) G<sub>1</sub> phase
- (c) G<sub>2</sub> phase
- (d) In both G<sub>1</sub> and G<sub>2</sub> phases

43. Four chromatids and two centromeres which are homologous occurs in

[CPMT 1995]

- (a) Zygotene                      (b) Diplotene
- (c) Diakinesis                      (d) Pachytene

44. The number of chromosome groups at the equatorial plate in metaphase-I of meiosis in a plant with  $2n = 50$  shall be

[MP PMT 1995, 98]

- (a) 50                      (b) 25
- (c) 30                      (d) 100

45. The significance of meiosis lies in

[NCERT; MP PMT 1995, 98; BVP 2003]

- (a) Reduction of the diploid number of chromosomes to haploid
- (b) Maintaining constancy in the number of diploid chromosomes during sexual reproduction
- (c) Production of genetic variability in the population of a species
- (d) All the above

46. During which phase(s) of cell cycle amount of DNA in a cell remains at 4C level if the initial amount is denoted as 2C

[CBSE PMT 2014]

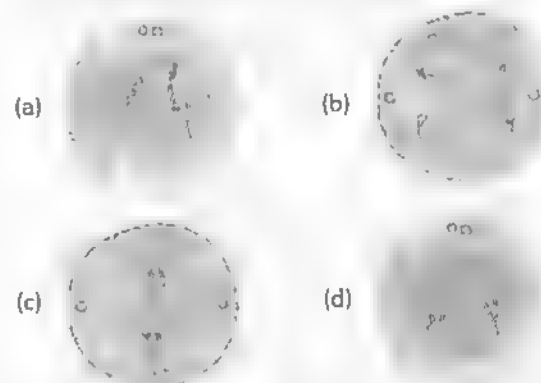
- (a) Only G<sub>2</sub>                      (b) G<sub>2</sub> and M
- (c) G<sub>0</sub> and G<sub>1</sub>                      (d) G<sub>1</sub> and S

47. The given figure represent a sequence in cell division



The missing stage in the above sequence is

[NCERT]



48. Identify the meiotic stage in which the homologous chromosomes separate while the sister chromatids remain associated at their centromeres

[NCERT;

Odisha JEE 2009; CBSE PMT (Malna) 2012;

PET (Pharmacy) 2013]

Or

In which stage of meiosis homologous chromosomes are segregated

[WB JEE 2016]

- (a) Metaphase I                      (b) Metaphase II
- (c) Anaphase I                      (d) Anaphase II

49. Which phase comes in between the  $G_1$  and  $G_2$  phase of cell cycle  
[WB JEE 2010]

Or

The formation of chromatid takes place in [Odisha JEE 2011]

- (a) M-phase (b)  $G_0$  - phase  
(c) S-phase (d) Interphase
50. During mitosis ER and nucleolus begin to disappear at  
[AFMC 1996; CBSE PMT (Pre.) 2010]
- (a) Early prophase (b) Late prophase  
(c) Early metaphase (d) Late metaphase
51. Match List I and List II and select the correct answer using the code given below in the lists :

List I (Phase of meiosis)		List II (Event that occurs)
1.	Prophase I	Crossing over occurs
2.	Metaphase I	Sister chromatids migrate to opposite poles
3.	Anaphase I	Homologous line up at equator in pairs

Code

[MP PMT 1993]

- (a) 1, 2 and 3 are correct  
(b) 1 and 2 are correct, 3 is false  
(c) 1 is correct, 2 and 3 are false  
(d) 1 and 3 are correct, 2 is false
52. Chromosome number is halved in meiosis during  
[NCERT; RPMT 2006]
- (a) Metaphase-I (b) Anaphase-I  
(c) Metaphase-II (d) Telophase-I
53. Yeast cell can progress through the cell cycle in about  
[NCERT; AMU (Med.) 2012]
- (a) 30 minutes (b) 60 minutes  
(c) 90 minutes (d) 120 minutes
54. Normal cellular activities, such as protein synthesis occur primarily during  
[Pune CET 1998]

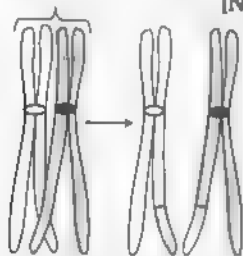
Or

Chromosome replicate in which stage of meiosis

[MP PMT 1994;

BHU 2002; WB JEE 2008; Odisha JEE 2008]

- (a) Interphase (b) Anaphase  
(c) Metaphase (d) Prophase
55. Given below is the representation of a certain event at a particular stage of a type of cell division. Which is this stage  
[NCERT; CBSE PMT (Pre.) 2012]



- (a) Prophase I during meiosis  
(b) Prophase II during meiosis  
(c) Prophase of Mitosis  
(d) Both prophase and metaphase of mitosis

56. In mitosis the movement of chromosomes requires  
[CPMT 1993]

(a) Presence of centromere (b) Plasmalemma  
(c) Spindle fibres (d) Nucleotides

57. DNA replication occurs during  
[MDAT Bihar 1995; MP PMT 2005; Odisha JEE 2010]

Or

The replication of centrioles occurs during

[MP PMT 1994; BHU 2004; WB JEE 2016]

Or

$G_1$ ,  $G_2$  and S phases are seen in which phase of the cell cycle  
[AFMC 2009]

(a) Prophase (b) Metaphase  
(c) Anaphase (d) Interphase  
(e) Leptotene

58. The given diagram shows a cell



Which of the following statements related to the image is not correct  
[NCERT]

- (a) The nuclear envelope is disappearing  
(b) The cell furrow is forming  
(c) It is an animal cell  
(d) It is in telophase
59. Meiosis is found at  
[MP PMT 2005]
- (a) Shoot apex (b) Reproductive part  
(c) Leaves bud (d) Vegetative parts
60. During cell division, sometimes there will be failure of separation of sister chromatids. This event is called  
[Kerala PMT 2004; WB JEE 2016]
- (a) Interference (b) Complementation  
(c) Coincidence (d) Non-disjunction
61. If a cell has a chromosome number after first meiosis equal to 48. The chromosome number in the daughter cells after the completion of meiosis will be  
[BHU 2001]
- (a) 48 (b) 24  
(c) 12 (d) 36
62. The given diagram is of a typical cell cycle



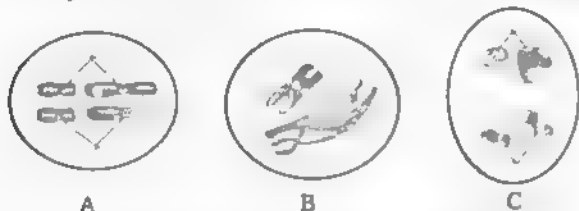
Identify the parts labelled as X, Y and Z  
[NCERT]

- (a) X -  $G_1$ ; Y -  $G_2$ ; Z -  $G_0$  (b) X -  $G_0$ ; Y - S; Z -  $G_2$   
(c) X -  $G_2$ ; Y - S; Z -  $G_1$  (d) X -  $G_1$ ; Y - S; Z -  $G_2$

63. Chiasmata formation takes place during  
[CPMT 1994, 2004; RPMT 1995;  
MP PMT 2002, 03, 06, 11; AMU (Med.) 2010]

(a) Prophase I (Diplotene) (b) Metaphase I  
(c) Anaphase II (d) Telophase I

64. The given figure represents various stages of cell division. Identify them [NCERT]



(a) A - Metaphase I, B - Prophase, C - Anaphase  
(b) A - Metaphase I, B - Prophase I, C - Anaphase I  
(c) A - Metaphase, B - Prophase I, C - Anaphase I  
(d) A - Metaphase, B - Prophase I, C - Anaphase

65. During the first metaphase of meiosis the centromeres  
[MP PMT 1994]

(a) Undergo division (b) Do not divide  
(c) Divide but do not separate (d) Are not identical

66. During gamete formation, the enzyme recombinase participates during [NCERT; CBSE PMT (Pre) 2012; CBSE PMT 2014]

(a) Metaphase - I (b) Anaphase - II  
(c) Prophase - I (Pachytene) (d) Prophase - II

67. Which of the following is unique to mitosis and not a part of meiosis [DUMET 2009]

(a) Homologous chromosomes behave independently  
(b) Chromatids are separated during anaphase  
(c) Homologous chromosomes pair and form bivalents  
(d) Homologous chromosomes crossover

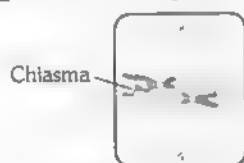
68. The protein for spindle fibre is  
[AIIMS 2001; WB JEE 2011; Odisha JEE 2011]

(a) Myosin (b) Actin  
(c) Troponin (d) Myoglobin

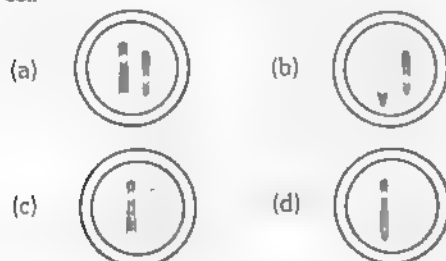
69. 56 cells are produced in meiosis in which [Odisha JEE 2011]

(a) First division is reductional (b) First division is equational  
(c) Second division is reductional (d) None of these

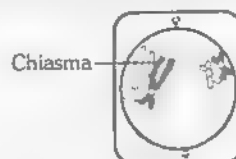
70. The given diagram of a cell undergoing meiosis, indicated that crossing over occurs only at the chiasma



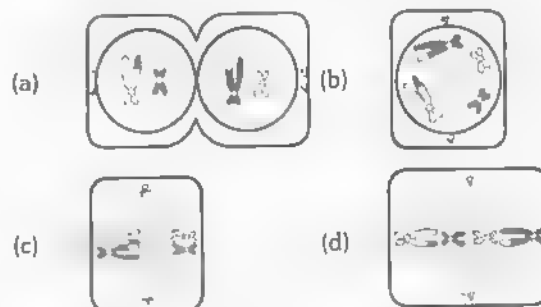
Which of the following gametes will NOT be formed from this cell [NCERT]



71. The given diagram shows a cell undergoing meiosis



Which diagram shows the next stage in the process [NCERT]



72. The process of mitosis is divided into 4 phases. Identify the correct order in which these phases appear in mitosis [MP PMT 1993]

(a) Anaphase, metaphase, telophase and prophase  
(b) Telophase, anaphase, metaphase and prophase  
(c) Metaphase, prophase, anaphase and telophase  
(d) Prophase, metaphase, anaphase and telophase

73. Meiosis and mitosis differ from each other because in meiosis [CPMT 1993]

(a) The four nuclei formed are not similar to parental ones  
(b) Homologous chromosomes pair and exchange parts  
(c) Number of chromosomes gets halved  
(d) All the above

74. Cell division is initiated by [CBSE PMT 1993]

(a) Centrosome (b) Centriole  
(c) Centromere (d) Chromomere

75. "Endomitosis" refers to

(a) Division of nucleus without chromosomal division  
(b) Division of chromosome without nuclear division  
(c) Division of cytoplasm  
(d) None of the above

76. The homologous chromosomes follow the process of synapsis in the stage or Pairing of homologous chromosome takes place in [DPMT 1995; MP PMT 1996, 99, 2011; RPMT 1997; BHU 2003; Haryana PMT 2005; J & K CET 2010; NEET (Karnataka) 2013]

Or

During which stage of meiosis, synaptonemal complex is formed [CPMT 2010; Odisha JEE 2011]

(a) Leptotene (b) Zygotene  
(c) Diplotene (d) Pachytene

77. At metaphase, chromosomes are attached to the spindle fibres by their [NCERT; Manipal 2005; CBSE PMT (Mains) 2011; NEET (Karnataka) 2013]

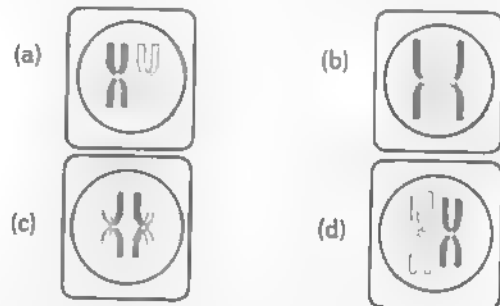
(a) Kinetochores (b) Centromere  
(c) Satellites (d) Secondary constrictions

78. The process of mitosis can be studied in  
[CPMT 1998, 2009; MHCET 2001; CBSE PMT 2002]  
(a) Onion root tip (b) Garlic root tip  
(c) Tendril tip (d) All of the above
79. Exchange of chromosome segments between maternal and paternal chromatids during meiosis is called  
[CBSE PMT 2000]

Or

- In meiosis the daughter cells are not similar to that of parent because of  
[AFMC 2005]  
(a) Linkage (b) Dominance  
(c) Crossing over (d) DNA multiplication
80. Mitotic stages are not observed in  
[KCET 2011]  
(a) *Cosmarium* (b) *E. coli*  
(c) *Saccharomyces* (d) *Chlorella*
81. Period of active mitosis ranges from  
(a) 10 minutes to a few hours (b) A few hours to a one day  
(c) One day to a week (d) Less than a minute
82. Which is synthesized in  $G_1$  phase  
[CPMT 2004]  
(a) DNA polymerase (b) Histones  
(c) Nucleolar DNA (d) Tubulin protein
83. How many meiotic divisions will be necessary to produce two hundred pollen grains  
[MP PMT 1999]  
(a) 50 (b) 100  
(c) 199 (d) 150
84. Prophase of reduction division is divided into number of stages. The correct chronological sequence is  
[CMC Vellore 1993; CPMT 1996, 2000; KCET 1999; Odisha PMT 2002; HP PMT 2005]  
(a) Leptotene — pachytene — zygotene — diplotene — diakinesis  
(b) Leptotene — diplotene — pachytene — zygotene — diakinesis  
(c) Leptotene — zygotene — diplotene — pachytene — diakinesis  
(d) Leptotene — zygotene — pachytene — diplotene — diakinesis
85. What is the correct sequence of the steps given here? Also work out the process depicted in the steps  
i. Homologous chromosomes move toward opposite poles of the cell; chromatids do not separate  
ii. Chromosomes gather together at the two poles of the cell and the nuclear membranes reform  
iii. Homologous chromosomes pair and exchange segments  
iv. Homologous chromosomes align on a central plate  
v. The haploid cells separate completely  
[AIIMS 2009]  
(a) The correct sequence is III → IV → I → II → V and the process is meiosis-I  
(b) The correct sequence is II → I → V → IV → III and the process is mitosis  
(c) The correct sequence is IV → I → III → II → V and the process is meiosis-I  
(d) The correct sequence is II → V → IV → I → II and the process is mitosis

86. Regarding the sequence of cell cycle, which one is correct  
[NCERT; MP PMT 1998; AIIMS 1999; CPMT 2002; RPMT 2005; WB JEE 2008, 12]  
(a)  $G_1$ ,  $G_2$ , S and M (b) S,  $G_1$ ,  $G_2$ , and M  
(c)  $G_1$ , S,  $G_2$  and M (d)  $G_2$ , S,  $G_1$ , and M
87. If we ignore the effect of crossing over, how many different haploid cells arise by meiosis in a diploid cell having  $2n=12$   
[AFMC 2006]  
(a) 8 (b) 16  
(c) 32 (d) 64
88. In which of the following stage, the chromosome is thin and like long thread  
[NCERT; AFMC 1997; MP PMT 2011; AMU (Med.) 2012]  
(a) Leptotene (b) Zygotene  
(c) Pachytene (d) Diakinesis
89. Which figure correctly represents a pair of homologous chromosomes at the start of meiosis  
[NCERT]



90. Diploid cells have  
[DUMET 2009]  
(a) Two chromosomes  
(b) One set of chromosomes  
(c) Two pairs of homologous chromosomes  
(d) Two sets of chromosomes
91. Calcium dependent kinases can control  
[AIIMS 2010]  
(a) Cell cycle activities (b) DNA replication  
(c) Cell surface receptors (d) Membrane structure
92.  $G_2$  phase of mitosis takes  
[BVP 2003]  
(a) 50% time of cell cycle (b) 25 to 33% time of cell cycle  
(c) 12 to 16% time of cell cycle (d) 4% time of cell cycle
93. Study the following lists

List-I		List-II	
(A)	Initiation of spindle fibres	(I)	Anaphase-I
(B)	Synthesis of RNA and protein	(II)	Zygotene
(C)	Action of endonuclease	(III)	$G_1$ phase
(D)	Movement of sister chromatids towards opposite poles	(IV)	Pachytene
		(V)	Anaphase-II

[NCERT; AFMC 1995; Pb. PMT 2004; BHU 2005; CPMT 2009; EAMCET 2009]

The correct match is

A	B	C	D
(a) II	III	IV	V
(b) III	II	I	V
(c) I	III	V	IV
(d) V	III	I	II

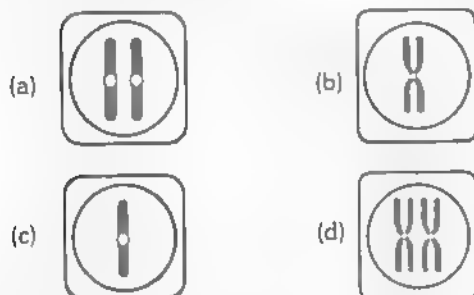
94. What is not seen during mitosis in somatic cells  
[DPMT 2006; NEET (Phase-I) 2016]

(a) Spindle fibres  
(b) Chromosome movement  
(c) Disappearance of nucleolus  
(d) Synapsis

95. The given figure shows a cell undergoing in Prophase I



Keeping the diagram in view which of the following diagram is correct for one of the cell at the end of meiosis [NCERT]



96. The microtubules from opposite poles of the spindle get attached to the kinetochores of sister chromatids in  
[AMU (Med.) 2009]

Or

At what phase of meiosis are there two cells, each with sister chromatids aligned at the spindle equator  
[Pune CET 1998; BHU 1999]

(a) Prophase II (b) Metaphase II  
(c) Anaphase II (d) None of these

97. Prophase is longer in [Manipal MEE 1995; CPMT 2001; MHCET 2001; WB JEE 2011]

(a) Mitosis (b) Meiosis  
(c) Equal in both (d) Amitosis

98. Which of the following characters is related with telophase  
[MP PMT 2009]

(a) Formation of nuclear membrane  
(b) Formation of nucleolus  
(c) Elongation of chromosome  
(d) Formation of two daughter nuclei

99. In which stage of cell division chromosomes are most condensed  
[WB JEE 2009; AIIMS 2010]

(a) Prophase (b) Metaphase  
(c) Anaphase (d) Telophase

100. Which of the following event takes place during Diplotene stage of prophase I of meiosis  
[DUMET 2010]

(a) Compaction of chromosomes  
(b) Formation of synaptonemal complexes  
(c) Formation of recombinational nodules  
(d) Dissolution of synaptonemal complex

101. The term "mitosis" was proposed by [MP PMT 2011]

(a) Flemming (b) Farmer  
(c) Moore (d) Boveri

102. Root cells of wheat has  $2n = 42$  chromosomes. Which one of the following is the basic chromosome number of wheat  
[WB JEE 2010]

(a) 42 (b) 21  
(c) 7 (d) 14

103. Which of the following structure will not be common to mitotic cell of a higher plant  
[CBSE PMT 1997]

(a) Cell plate (b) Centromere  
(c) Centriole (d) Spindle fibre

104. How many mitotic divisions are needed for a single cell to make 128 cells  
[CBSE PMT 1997; AFMC 1999, 2002; Odisha JEE 2010]

(a) 7 (b) 14  
(c) 28 (d) 32

105. Which one of the following forms the spindle apparatus during cell division  
[Kerala CET 2002]

(a) Chromosome (b) Centrosome  
(c) Ribosome (d) Chondriosome

106. During cell division in apical meristem nuclear membrane reappears in  
[CBSE PMT 1997]

(a) Interphase (b) Telophase  
(c) Prophase (d) S phase

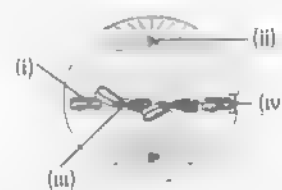
107. Cell in  $G_0$  phase of cell cycle [WB JEE 2009]

(a) Exit cell cycle (b) Enter cell cycle  
(c) Suspend cell cycle (d) Terminate cell cycle

108. How many reduction divisions are necessary for the formation of 200 grains of wheat  
[MHCET 2002]

(a) 250 (b) 150  
(c) 200 (d) 360

109. See the following figure and identify marked lines (i), (ii), (iii) and (iv)  
[NCERT]



(a) (i) Chromosome, (ii) Centromere, (iii) Centriole, (iv) Chromatid  
(b) (i) Chromatid, (ii) Centromere, (iii) Centriole, (iv) Chromosome  
(c) (i) Chromosome, (ii) Centriole, (iii) Centromere, (iv) Chromatid  
(d) (i) Chromatid, (ii) Centriole, (iii) Centromere, (iv) Chromosome

110. The non-sister chromatids twist around and exchange segments with each other during or In meiosis crossing over is initiated at  
[Kerala PMT 2009; WB JEE 2011; NEET (Phase-I) 2016]

(a) Diplotene (b) Diakinesis  
(c) Leptotene (d) Pachytene  
(e) Zygotene



111. During mitosis chromosomes go to their poles in a stage called [CPMT 1994; MP PMT 2001; DPMT 2003; BHU 2004]

Or

The shape of chromosome is clearly visible at

[Odisha JEE 2009]

- (a) Prophase (b) Metaphase  
(c) Anaphase (d) Telophase
112. The number of mitotic cell division required to produce 256 cells from single cell would be [KCET 2007]

(a) 10 (b) 12  
(c) 6 (d) 8

113. DNA replication takes place in [MP PMT 2009; AFMC 2010; WB JEE 2016]

Or

DNA molecule of each chromosome become double in

[NCERT; CPMT 1996, 2001, 10;

MP PMT 1994, 99, 2001, 02, 06, Kashmir MEE 1995;

CBSE PMT 1996, 2001; RPMT 1997; Pb. PMT 1999; Kerala PMT 2006]

Or

DNA and histone proteins are synthesized during the following phase of cell cycle

[DPMT 2004; CBSE PMT 2005; NEET (Phase-II) 2016]

- (a)  $G_1$  phase (b)  $G_2$  phase  
(c) S phase (d) Mitotic phase
114. During the meiotic division the [BHU 2005]
- (a) Homologous chromosomes are separated  
(b) The linkage is disturbed  
(c) The homologous chromosomes do not segregate  
(d) All of the above
115. The number of chromosomes after 1 phase of meiotic division in reduction division [CPMT 1994]
- (a) Remain unchanged (b) Become doubled  
(c) Become halved (d) None of the above

116. Meiosis can be observed in [MP PMT 1992, 96; CPMT 1994; WB JEE 2008]

(a) Root tips (b) Cambium  
(c) Anther (PMC) (d) Pollen grains

117. Select the correct match

A.	S phase	-	DNA replication
B.	Zygotene	-	Synapsis
C.	Diplotene	-	Crossing over
D.	Meiosis	-	Both haploid and diploid cells
E.	Gap 2 phase	-	Quiescent stage

[Kerala PMT 2011]

- (a) A and B (b) C and D  
(c) C and E (d) A, C and E  
(e) A and D

118. During meiosis, the alleles of the parental pair separate or segregate from each other. How many allele(s) are then transmitted to a gamete [Kerala PMT 2011]

(a) Four (b) Two  
(c) Six (d) One  
(e) Eight

119. In meiosis I, a bivalent is an association of [NCERT; Kerala PMT 2007]

(a) Four chromatids and four centromeres  
(b) Two chromatids and two centromeres  
(c) Two chromatids and one centromere  
(d) Two chromatids and four centromeres  
(e) Four chromatids and two centromeres

120. Cell division can not be stopped in which phase of the cell cycle [WB JEE 2010]

(a)  $G_1$  - phase (b)  $G_2$  - phase  
(c) S - phase (d) Prophase

121. Cell plate is referred as [MP PMT 1994; MHCET 2001; JIPMER 2002; Odisha JEE 2004]

(a) Germplast (b) Idioblast  
(c) Phragmoplast (d) Middle lamella

122. In which phase proteins for spindle fibre formation are synthesized [Odisha JEE 2004]

(a)  $G_1$  phase (b)  $G_2$  phase  
(c) S-phase (d) Anaphase

123. Karyokinesis differ from cytokinesis because it involves [MP PMT 1994, 2003]

(a) Division of cytoplasm  
(b) Division of the nucleus and cytoplasm  
(c) Division of the nucleus  
(d) Division of the cell

124. Differentiated cell arrests at which stage [DPMT 2007]

(a)  $G_1$  (b)  $H_2$   
(c)  $G_0$  (d) U

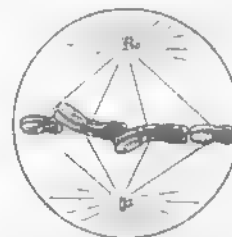
125. The nuclear membrane disappears in [CPMT 1993; MP PMT 1995, 98; J & K CET 2002]

(a) Metaphase (b) Early prophase  
(c) Late prophase (d) Anaphase

126. Chromonemata start associating into bivalent chromosomes during [MP PMT 1997; J & K CET 2002]

(a) Zygotene (b) Leptotene  
(c) Pachytene (d) Diplotene

127. Select the correct option with respect to mitosis



[CBSE PMT (Pre.) 2011; NEET (Karnataka) 2013]

- (a) Chromosomes move to the spindle equator and get aligned along equatorial plate in metaphase  
(b) Chromatids separate but remain in the centre of the cell in anaphase  
(c) Chromatids start moving towards opposite poles in telophase  
(d) Golgi complex and endoplasmic reticulum are still visible at the end of prophase

- 128.** Which one of the following precedes re-formation of the nuclear envelope during *M* phase of the cell cycle  
[NCERT; CBSE PMT 2004; AIIMS 2008]  
(a) Formation of the contractile ring, and formation of the phragmoplast  
(b) Formation of the contractile ring, and transcription from chromosomes  
(c) Decondensation of chromosomes, and reassembly of the nuclear lamina  
(d) Transcription from chromosomes, and reassembly of the nuclear lamina
- 129.** In an organism, if the normal diploid number of chromosomes is 8, how many chromatids are present in each daughter cell at the end of meiosis I [MP PMT 1993]  
(a) 2 (b) 4  
(c) 8 (d) 16
- 130.** In eukaryotic cell cycle, cell fusion experiments show that [AIEEE Pharmacy 2004]  
(a) When an S-phase cell is fused with a  $G_1$ -phase cell,  $G_1$ -phase cell is stimulated to synthesise DNA  
(b) When an S-phase cell is fused with a  $G_2$ -phase cell, DNA synthesis is induced in  $G_2$ -phase cell.  
(c) When a  $G_1$ -phase cell is fused with a  $G_2$ -phase cell, DNA synthesis is induced in both  $G_1$  and  $G_2$  phase cells  
(d) When a  $G_1$ -phase cell is fused with an M-phase cell both  $G_1$  and M phase cells are stimulated to synthesise DNA
- 131.** The points at which crossing over has taken place between homologous chromosomes are called [Pune CET 1998; BHU 2001]  
Or  
Visible expression of the genetic phenomenon of crossing over is called [KCET 2012]  
(a) Protein axis (b) Synaptonemal complexes  
(c) Chiasmata (d) Centromeres
- 132.** How many meiotic division would be required to produce 101 female gametophytes in an angiosperm [Pb. PMT 1997]  
(a) 101 (b) 26  
(c) 127 (d) None of these
- 133.** Mitotic spindle have main protein [BHU 2006; MP PMT 2007]  
(a) Tubulin (b) Myosin  
(c) Tropomyosin (d) Dynein
- 134.** Cells of certain species of animals have six pairs of chromosomes. How many molecules of DNA will remain in a nucleus of these animals during  $G_2$  phase [WB JEE 2016]  
(a) 12 (b) 48  
(c) 6 (d) 24
- 135.** Which of the following is not true for meiosis [WB JEE 2016]  
(a) Production of genetic variability  
(b) Maintaining constancy of chromosome number during sexual reproduction  
(c) Reduction of chromosome number to one half  
(d) Production of diploid cell
- 136.** Which of the following is used as the mitotic spindle poison [WB JEE 2016]  
(a)  $Ca^{++}$  (b)  $Mg^{++}$   
(c) Tubulin (d) Colchicine
- 137.** Progression of cell cycle is regulated by the concentration of which type of molecule [WB JEE 2016]  
(a) Centrosomes (b) Cyclin-dependent kinases  
(c) Cyclins (d) Microtubules
- 138.** When cell has stalled DNA replication fork, which checkpoint should be predominantly activated [NEET (Phase-II) 2016]  
(a) Both  $G_2/M$  and M (b)  $G_1/S$   
(c)  $G_2/M$  (d) M
- 139.** Match the stages of meiosis in Column-I to their characteristic features in Column-II and select the correct option using the codes given below [NEET (Phase-II) 2016]
- | Column-I        | Column-II                                  |
|-----------------|--|
| (A) Pachytene   | (i) Pairing of homologous chromosomes      |
| (B) Metaphase I | (ii) Terminalization of chiasmata          |
| (C) Diakinesis  | (iii) Crossing-over takes place            |
| (D) Zygotene    | (iv) Chromosomes align at equatorial plate |
- | Codes | (A)   | (B)   | (C)   | (D)   |
|-------|-------|-------|-------|-------|
| (a)   | (iv)  | (iii) | (ii)  | (i)   |
| (b)   | (iii) | (iv)  | (ii)  | (i)   |
| (c)   | (i)   | (iv)  | (ii)  | (iii) |
| (d)   | (ii)  | (iv)  | (iii) | (i)   |
- 140.** Anaphase promoting Complex (APC) is a protein degradation machinery necessary for proper mitosis of animal cells. If APC is defective in a human cell, which of the following is expected to occur [NEET 2017]  
(a) Chromosomes will not condense  
(b) Chromosomes will be fragmented  
(c) Chromosomes will not segregate  
(d) Recombination of chromosome arms will occur
- 141.** Which of the following options gives the correct sequences of events during mitosis [NEET 2017]  
(a) Condensation → nuclear membrane disassembly → crossing over → segregation → telophase  
(b) Condensation → nuclear membrane disassembly → arrangement at equator → centromere division → segregation → telophase  
(c) Condensation → crossing over → nuclear membrane disassembly → segregation → telophase  
(d) Condensation → arrangement at equator → centromere division → segregation → telophase



- 1.** Select the correct statement about  $G_1$  phase [NCERT]  
(a) Cell is metabolically inactive  
(b) DNA in the cell does not replicate  
(c) It is not a phase of synthesis of macromolecules  
(d) Cell stops growing

2. At which stage of meiosis कसमे the genetic constitution of gametes is finally decided [NCERT]  
(a) Metaphase I (b) Anaphase II  
(c) Metaphase II (d) Anaphase I
3. Meiosis occurs in organisms during [NCERT]  
(a) Sexual reproduction  
(b) Vegetative reproduction  
(c) Both sexual and vegetative reproduction  
(d) None of the above
4. During anaphase-I of meiosis [NCERT]  
(a) Homologous chromosomes separate  
(b) Non-homologous autosomes separate  
(c) Sister chromatids separate  
(d) Non-sister chromatids separate
5. Mitosis is characterised by [NCERT]  
(a) Reduction division  
(b) Equal division  
(c) Both reduction and equal division  
(d) None of the above
6. Identify the wrong statement about meiosis [NCERT]  
(a) Pairing of homologous chromosomes  
(b) Four haploid cells are formed  
(c) At the end of meiosis the number of chromosomes are reduced to half  
(d) Two cycle of DNA replication occurs
7. Cells which are not dividing are likely to be at [NCERT]  
(a) G<sub>1</sub> (b) G<sub>2</sub>  
(c) G<sub>0</sub> (d) S phase
8. Which of the events listed below is not observed during mitosis [NCERT]  
(a) Chromatin condensation  
(b) Movement of centrioles to opposite poles  
(c) Appearance of chromosomes with two chromatids joined together at the centromere.  
(d) Crossing over
4. Which one of the following pairs is correctly matched [MP PMT 1993]  
(a) Anaphase I – Homologous chromosomes are separated  
(b) Metaphase I – Pairing of maternal and paternal homologous chromosomes takes place  
(c) Interphase – A nuclear envelope encloses each haploid set of chromosomes  
(d) Prophase I – Non-homologous chromosomes are separated
5. Chromosome start separating at which stage of mitosis [AFMC 1996]  
(a) Early metaphase (b) Late metaphase  
(c) Early anaphase (d) Early telophase
6. The number of chromatids in a chromosome at anaphase is [CBSE PMT 1992; BHU 1994; AFMC 1995]  
(a) 2 in mitosis and 1 in meiosis  
(b) 1 in mitosis and 2 in meiosis  
(c) 2 each in mitosis and meiosis  
(d) 2 in mitosis and 4 in meiosis
7. The major event that occurs during the anaphase of mitosis, which brings about the equal distribution of chromosomes, is [KCET 2006]  
(a) Replication of the genetic material  
(b) Splitting of the chromatids  
(c) Splitting of the centromeres  
(d) Condensation of the chromatin
8. In the somatic cell cycle [CBSE PMT 2004]  
(a) A short interphase is followed by a long mitotic phase  
(b) G<sub>2</sub> phase follows mitotic phase  
(c) In G<sub>1</sub> phase DNA content is double the amount of DNA present in the original cell  
(d) DNA replication takes place in S-phase
9. A stage in cell division is shown in the figure. Select the answer which gives correct identification of the stage with its characteristics



[NEET 2013]

- Critical Thinking**  
**Objective Questions**
1. Pick out the correct statements  
(A) Mitosis takes place in the somatic cells and meiosis takes place in the germ cells  
(B) During mitosis, the DNA replicates once for one cell division and in meiosis the DNA replicates twice for two cell divisions  
(C) Mitosis and meiosis occur both in sexually and asexually reproducing organisms [Kerala PMT 2008]  
(a) (A) only (b) (B) only  
(c) (C) only (d) (A) and (B) only  
(e) (B) and (C) only
2. The number of DNA in chromosome at G<sub>2</sub> stage of cell cycle [RPMT 2002]  
(a) One (b) Two  
(c) Four (d) Eight
3. While working in a lab, a student forgot to add colchicine while karyotyping through blood culture technique, Then what will happen [GUJCET 2014]  
(a) Mitosis will be arrested at metaphase  
(b) Chromosomal division will continue and each chromosome will have four arms  
(c) Chromosomal division will continue  
(d) Mitosis will be arrested at telophase

(a)	Telophase	Endoplasmic reticulum and nucleolus not reformed yet
(b)	Telophase	Nuclear envelop reforms, Golgi complex reforms
(c)	Late anaphase	Chromosomes move away from equatorial plate, Golgi complex not present
(d)	Cytokinesis	Cell plate formed, mitochondria distributed between two daughter cells

10. Meiosis takes place in [NEET 2013]  
 (a) Megaspore (b) Meiocyte  
 (c) Conidia (d) Gemmule
11. The complex formed by a pair of synapsed homologous chromosomes is called [NEET 2013]  
 (a) Axoneme (b) Equatorial plate  
 (c) Kinetochore (d) Bivalent
12. DNA replication in bacteria occurs [NEET 2017]  
 (a) During S phase (b) Within nucleolus  
 (c) Prior to fission (d) Just before transcription

8. Assertion : During zygotene, chromosomes show bivalent stage.  
 Reason : Bivalent is half the number of chromosomes.
9. Assertion : Meiosis takes place in pollen mother cells.  
 Reason : Each pollen mother cell produce 4 haploid pollen grains. [AIIMS 1996]
10. Assertion : Meiotic division results in the production of haploid cells.  
 Reason : Synapsis occurs during zygotene of meiosis. [AIIMS 1998]

## R Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

- (a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion  
 (b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion  
 (c) If the assertion is true but the reason is false  
 (d) If both the assertion and reason are false  
 (e) If the assertion is false but reason is true

1. Assertion : Synthesis of DNA takes place in the S-phase of interphase.  
 Reason : Every chromosome, during metaphase, has two chromatids. [KCET 2010]
2. Assertion : Reduction division occurs in anaphase-I. So there is no need of meiosis.  
 Reason : Meiosis-II occurs to separate homologous chromosomes. [AIIMS 2009]
3. Assertion : Karyokinesis occurs in M-phase.  
 Reason : Cell division stops in M-phase.
4. Assertion : Interphase is resting stage.  
 Reason : The interphase cell is metabolically inactive.
5. Assertion : DNA synthesis occurs in  $G_1$  and  $G_2$  periods of cell cycle.  
 Reason : During  $G_1$  and  $G_2$  phase the DNA contents become double.
6. Assertion : Mitosis maintains the genetic similarity of somatic cells.  
 Reason : Chromosomes do not undergo crossing over.
7. Assertion : Chiasmata is formed during diplotene.  
 Reason : Chiasmata are formed due to deposition of nucleoproteins.

## Answers

### Cell division

1	d	2	d	3	c	4	a	5	c
6	b	7	b	8	c	9	a	10	d
11	d	12	c	13	a	14	d	15	d
16	d	17	a	18	a	19	b	20	b
21	d	22	d	23	c	24	a	25	c
26	c	27	d	28	a	29	b	30	a
31	d	32	a	33	a	34	b	35	a
36	a	37	a	38	b	39	c	40	a
41	d	42	d	43	a	44	b	45	d
46	a	47	c	48	c	49	c	50	a
51	c	52	b	53	c	54	a	55	a
56	c	57	d	58	a	59	b	60	d
61	a	62	d	63	a	64	b	65	b
66	c	67	a	68	b	69	a	70	a
71	c	72	d	73	d	74	a	75	b
76	b	77	a	78	d	79	c	80	b
81	a	82	a	83	a	84	d	85	a
86	c	87	d	88	a	89	a	90	d
91	a	92	c	93	a	94	d	95	c
96	b	97	b	98	d	99	b	100	d
101	a	102	c	103	c	104	a	105	b
106	b	107	c	108	a	109	d	110	d
111	c	112	d	113	c	114	a	115	c
116	c	117	a	118	d	119	e	120	c
121	c	122	a	123	c	124	c	125	c
126	a	127	a	128	c	129	c	130	b
131	c	132	a	133	a	134	d	135	d
136	d	137	b	138	b	139	b	140	c
141	b								

## NCERT Exemplar Questions

1	b	2	d	3	a	4	a	5	a
6	d	7	c	8	d				

## Critical Thinking

1	a	2	b	3	c	4	a	5	c
6	b	7	c	8	d	9	b	10	b
11	d	12	c						

## Assertion and Reason

1	a	2	b	3	d	4	c	5	d
6	a	7	c	8	b	9	a	10	a

# S

## Answers and Solutions

## Cell division

4. (a) Condensation of chromosomes occurs in the prophase-I. After that chromosome moves toward the poles.
6. (b) The most important role of meiosis is to maintain haploid phase.
9. (a) Colchicine is obtained from colchicum autumnale plant, which inhibits the formation of spindle fibers in metaphase.
10. (d) When cells are not to divide after  $G_1$  phase and start undergoing differentiation into specific types of cells such cells are said to be in  $G_0$  phase/ $G_0$  state.
14. (d) Cyclin is a protein, which participates in cell division.
15. (d) Diakinesis is the stage of meiosis. For the study of meiosis young flower bud is the best material.
16. (d) Leptotene, zygotene, pachytene, diplotene and diakinesis all are successive stages of meiosis.
17. (a) Synaptonemal complex is formed during meiotic prophase first.
18. (a) Synaptonemal complex is formed in meiotic prophase-I, which was first observed by Moses in 1956.
19. (b) Knot like structure 'Chromomeres' found in the stage leptotene of prophase first of meiosis.
20. (b) During meiosis, daughter cells has the half number of chromosomes with respect to parent cells. Therefore daughter cell will be genetically different.
22. (d) In meiosis, crossing over takes place in pachytene, after that chromosome get repulsion in diplotene.
23. (c) During cleavage, cell divides mitotically without taking any gap, so that is known as closed mitosis.

27. (d) During the pachytene, chromosomes get crossed with each other and forms a four stranded or tetrad appearance.
29. (b) The crossing over of homologous chromosome occurs in Pachytene of prophase first of meiosis. It is known as recombination.
34. (b) Gamete is haploid while somatic cell is diploid. After S-phase it will contain twice the number of chromosomes and four times the amount of DNA.
35. (a) In prophase I of meiosis I, the correct sequence of events are  
B – synapsis in Zygotene  
C – crossing over in pachytene in diakinesis  
D – disappearance of nucleolus in diakinesis
38. (b) Because in metaphase, chromosomes are present in bivalent form on equator. Chromosomes are much condense and well visible
39. (c) S or synthesis phase marks the period where DNA synthesis takes place. During this time the amount of DNA per cell doubles.
41. (d) In meiosis II division is equational division; thus centromere divides and chromatid move towards the pole during anaphase-II.
44. (b) One chromosome forms one chromosome group in metaphase-I after splitting of tetravalent condition.
46. (a) In M=phase, both 4C and 2C of DNA are present in different stages.
49. (c) The sequence of interphase (I-Phase) is  $G_1 \rightarrow S \rightarrow G_2$ .
55. (a) Diagram first represents crossing over that takes place in pachytene stage of prophase I during meiosis.
56. (c) Because they are thread like structures, which contract to pull the chromosome towards pole.
57. (d) Because interphase is the growth phase of cell. Centrioles replicate in  $G_2$  of interphase of cell cycle but some authors reported this duplication in early prophase.
66. (c) Crossing over is an enzyme-mediated process and the enzyme involved is called recombinase.
73. (d) All the above; four nuclei formed are not similar to parent ones because they are haploid in nature. Homologous chromosome pairs are exchange parts because in crossing over exchange of chromatid arms takes place and number of chromosomes gets halved.
76. (b) In zygotene of prophase of meiosis, chromosomes pairing occurs for crossing over.
83. (a) Because one cell produces 4 daughter cells after meiotic division, thus 50 cells produce  $50 \times 4 = 200$  daughter cells.
85. (a) III-Prophase, IV-Metaphase, I-Anaphase (I), II-Telophase (I), V-Telophase (III)
87. (d) The number of different haploid cells arise by meiosis can be calculated by  $2^n$   
 $n$  = number of haploid chromosome.

88. (a) Leptotene is a stage in the prophase I of meiosis. In this stage chromosome appears thin and long.
91. (a) Calcium Dependent Kinases (CDKs) have the ability to control cell cycle activities during cell division.
94. (d) Synapsis is the pairing of homologous chromosomes during zygotene stage of prophase I of meiotic division-I. The homologous chromosomes come from the mother and father.
102. (c) For wheat,  $2n = 6x = 42$ .  
 $\therefore x = 7$   
 'x' represents basic or genomic number.
103. (c) Centrioles are organelles important in spindle formation during nuclear division. These are found commonly in most animal cells and some lower plant cells.
104. (a) A single mitotic division results in the production of two cells from a single one.
108. (a) For the formation of 100 grains of wheat 100 pollen grains and 100 megaspores are required. Each microspore mother cell produces 4 microspores (pollen grains) as a result of reduction division. Hence for the formation of 100 pollen grains,  $\frac{100}{4} = 25$  PMC are needed and each will undergo one reduction division. Each megaspore mother cell will produce 4 megaspores in which one become functional and other three degenerate. Thus each MMC produces one megaspore. So 100 MMC are required to produce 100 megaspores. Total number of reduction divisions to produce 100 grains is  $100 + 25 = 125$ .
112. (d) Mitotic cells division is equational division where a mother cell divides to form 2 daughter cells. So to produce 256 cells from a single cell, 8 mitotic divisions will occur which can be represented as  $1 \rightarrow 2 \rightarrow 4 \rightarrow 8 \rightarrow 16 \rightarrow 32 \rightarrow 64 \rightarrow 128 \rightarrow 256$ .
115. (c) Because first phase of meiosis includes reduction division while second phase exhibits mitotic divisions.
116. (c) As a result of it pollen grains formed.
120. (c) The check points are basically present in the interphase.
126. (a) Pairing between the homologous chromosomes takes place in zygotene stage of prophase-I.
129. (c) Because each chromosome bears two chromatids and at the end of meiosis-I chromosome number becomes halved i.e., 4 and number of chromatids are  $4 \times 2 = 8$ .
134. (d)  $G_1 \rightarrow 6$  pairs or 12 chromosomes or 12 chromatids or 12 DNA molecules. After S or  $G_2 \rightarrow 6$  pairs or 12 chromosomes or 24 chromatids or 24 DNA molecules.
135. (d) As a result of meiosis only haploid cells are produced.
136. (d) Spindle depolymerization is caused by Colchicine.
138. (b) DNA replication occurs in S-phase of cell cycle.

### Critical Thinking

2. (b) The duplication of DNA takes place in 'S' stage of interphase after that cell reaches in  $G_2$  phase. That is why the strand of DNA in  $G_2$  phase will be two.
3. (c) In absence of colchicines mitotic division will be continued in normal way.
8. (d) In the somatic cell cycle S-phase is a stage of replication of each chromosome by synthesis of a new DNA molecule on the template of existing DNA.

### Assertion and Reason

1. (a)
2. (b) Anaphase-I involves separation of homologous chromosomes into different daughter cells. So, meiosis I is a reductional division. But each chromosome is still formed of two sister chromatids joined at the common centromeres. Anaphase-I results in reduction in number of chromosomes but each chromosome has double amount of DNA, so, meiosis-II occurs, during, which chromatids of each chromosome separate into different cells. Main aim of meiosis II is to separate genetically modified chromatids of each homologous chromosome formed during crossing over in meiosis-I.
3. (d) M-phase represents the phase of actual division. It consists of karyokinesis (The division of nucleus) followed by cytokinesis (The division of cytoplasm). Cell divisions stop after M-phase.
4. (c) Previously interphase is called resting stage because there is no apparent activity related to cell division. The interphase cell is metabolically quite active. Interphase consist of three subphases ( $G_1$ ,  $G_2$  and S). Synthesis of DNA occurs in S phase.  $G_1$  is the period between the end of mitosis and the start of S phase.  $G_2$  is the interval between S phase and start of mitosis. As the synthesis of DNA occurs in S phase so it is considered as metabolically active phase.
5. (d) The synthesis of DNA occurs only in a restricted portion of the interphase during S period, which is preceded and followed by two "gap" periods of interphase ( $G_1$  and  $G_2$ ) in which there is no DNA synthesis.  $G_1$  is the period between the end of mitosis and the start of DNA synthesis. S is the period of DNA synthesis and  $G_2$ , the interval between the end of DNA synthesis and the start of mitosis. During  $G_2$  a cell contains two times (4C) the amount of DNA present in the original diploid cell (2C). Following mitosis the daughter cell again enter the  $G_1$  period and have a DNA content equivalent to 2C.
6. (a) Mitosis keeps all the somatic cells of an organism genetically similar, resembling the fertilized egg. Mitosis involves replication and equitable distribution of all the chromosomes so that all the cells of a multicellular organism have the same number and type of chromosomes. This helps in proper co-ordination among different cells.
7. (c) The points of attachment between the homologous chromosomes after the partial dissolution of nucleoprotein complex are called chiasmata. It occurs during diplotene substage of prophase I.
8. (b) During zygotene, because of the pairing of the homologous, the nucleus contains half the number of chromosomes. Each unit is a bivalent composed of two homologous chromosomes.
9. (a) Meiosis occurs in pollen mother cells. All pollen mother cells are diploid and produce haploid pollen grains after meiosis.
10. (a) Diploid cell produce haploid cell by meiosis. It occurs due to synapsis. A chromosome has two chromatids, hence a bivalent has 4 chromatids.

## Cell Cycle and Cell Division

## Self Evaluation Test

- Bivalents in meiosis are [RPMT 2001]
  - Tetrad
  - Pairs of non-homologous chromosomes
  - Pairs of several chromatids
  - Pairs of homozygous chromosomes
- Which type of cell division occurs in the gonads [RPMT 2001]
  - Mitosis only
  - Meiosis
  - Both (a) and (b)
  - Amitosis and meiosis
- The spindle fibre contracts in [KCET 1998]
  - Metaphase I
  - Anaphase II
  - Prophase II
  - Telophase II
- If there were 4 chromosomes present during prophase, how many chromosomes are there in each cell at the end of anaphase II [Pune CET 1998]
  - 16
  - 4
  - 2
  - 8
- Which is not characteristic of meiosis [AIIMS 2011]
  - Two stages of DNA replication, first before meiosis I and second before meiosis II
  - Recombination and crossing over
  - Sister chromatids separate during anaphase II
  - Nuclear membrane disappears towards end of prophase
- Cell division in blue-green algae is more or less similar to that in [MP PMT 1994]
  - Red algae
  - Green algae
  - Brown algae
  - Bacteria
- Which out of the following is not a divisional stage
  - Telophase
  - Interphase
  - Metaphase
  - Prophase
- Crossing over is advantageous because it brings about
  - Variation
  - Linkage
  - Inbreeding
  - Stability
- Cellular structure always disappears during mitosis is
  - Cell wall
  - Cell membrane
  - Nucleolus
  - All the above
- Anastral mitosis is found in [MHCET 2001]
  - Animals
  - Higher plants
  - Bacteria
  - Cyanobacteria

## Answers and Solutions

1	a	2	c	3	b	4	c	5	a
6	d	7	b	8	a	9	c	10	b

- (a) Bivalent formation occurs in pachytene of meiosis. In this stage, two chromatids of homologous chromosome (Bivalent) later on forms a cross and now showing a tetravalent or tetrad stage.
- (c) Mitosis and meiosis both type of cell division occurs in gonads. Mitosis during growth and development and meiosis during gametogenesis.

\* \* \*



## Chapter

# 4.1

## Transport in Plants

Plant physiology (Physis = nature of life; logos = study) is the branch of botany which deals with the study of life activities of plants. It includes the functional aspects of life processes both at cellular as well as sub-cellular level.

### Concept of water relation

Water is mainly absorbed by the roots of the plants from the soil, then it moves upward to different parts and is lost from the aerial parts, especially through the leaves. Before taking up the absorption and movement of water in plants, it is worthwhile to understand the phenomenon of imbibition, diffusion and osmosis involved in the water uptake and its movement in the plants.

**Imbibition (L. Imbibere – to drink) :** The process of adsorption of water by hydrophilic surfaces of a substance without forming a solution is called 'imbibition'. It is a type of diffusion by which movement of water takes place along a diffusion gradient. The solid particles which adsorb water or any other liquid are called imbibants. The liquid which is imbibed is known as imbibate.

**Characteristics of imbibition :** The phenomenon of imbibition has three important characteristics .

(i) **Volume change :** During the process of imbibition, imbibants increase in volume. It has been observed that there is an actual compression of water. This is due to arrangement of water molecules on surface of imbibant and occupy less volume than the same molecules do when are in free stage in the normal liquid. e.g., If a dry piece of wood is placed in water, they swell and increases in its volume

(i.) **Production of heat :** As the water molecules are adsorbed on the surface of the imbibant, their kinetic energy is released in the form of heat which increases the temperature of the medium. It is called heat of wetting (or heat of hydration). e. g., during kneading, the flour of wheat gives a warm feeling due to imbibition of water and consequent release of heat.

(iii) **Development of imbibitional pressure :** Imbibition pressure can be defined as the maximum pressure that an imbibant will develop when it is completely soaked in pure water. Imbibition pressure is also called as the matric potential because it exists due to the presence of hydrophilic substances in the cell which include organic colloids and cell wall.

### Factors influencing the rate of imbibition

**Nature of imbibant :** Proteins are the strongest imbibants of water, starch less strong, cellulose being the weakest.

**Surface area of imbibant :** If more surface area of the imbibant is exposed and is in contact with liquid, the imbibition will be more

**Temperature :** Increase in temperature causes an increase in the rate of imbibition.

**Degree of dryness of imbibant :** If the imbibant is dry it will imbibe more water than a relatively wet imbibant.

**Concentration of solutes :** Increase in the concentration of solutes in the medium decreases imbibition.

**pH of imbibant :** Proteins, being amphoteric in nature, imbibe least in neutral medium. Towards highly acidic or highly alkaline pH, the imbibition increases till a maximum is reached, there after it starts slowing down.

### Significance of imbibition

(1) The water is first imbibed by walls of root hairs and then absorbed.

(2) Water is absorbed by germinating seeds through the process of imbibition and helps in rupturing of seed coat (made up of cellulose).

(3) The water moves into ovules which are ripening into seeds by the process of imbibition.



**Diffusion** : The movement of the molecules of gases, liquids and solids from the region of higher concentration to the region of lower concentration is known as diffusion.

It may occur between gas and gas (e.g., diffusion of ammonia into air), liquid and liquid (e.g., diffusion of alcohol into water), or solid and liquid (e.g., diffusion of sugar into water).

**Diffusion pressure** : It is a hypothetical term coined by Meyer (1938) to denote the potential ability of the molecules or ions of any substance to diffuse from an area of their higher concentration to that of their lower concentration.

**Diffusion pressure deficit (DPD) or Suction pressure (SP)** : The term diffusion pressure (DP) and diffusion pressure deficit (DPD) were put forth by B.S. Meyer in 1938. Now a days, the term water potential ( $\psi$ ) is used which is equal to DPD, but negative in value. The term suction pressure was put forth by Renner (1915).

The amount by which the diffusion pressure of water or solvent in a solution is lower than that of pure water or solvent is known as diffusion pressure deficit (DPD). Diffusion pressure deficit is the water absorbing capacity of a solution. Therefore, DPD can also be called **suction pressure (SP)**.

#### Factors influencing rate of diffusion

**Temperature** : Increase in temperature leads to increase in the rate of diffusion.

**Pressure** : The rate of diffusion of gases is directly proportional to the pressure. So the rate of diffusion increases with increase in pressure. Rate of diffusion  $\propto$  pressure.

**Size and mass of diffusing substance** : Diffusion of solid is inversely proportional to the size and mass of molecules and ions.

$$\text{Rate of diffusion} \propto \frac{1}{\text{Size} \times \text{Mass of particles}}$$

**Density of diffusing substance** : The rate of diffusion is inversely proportional to the square root of density of the diffusing substance. Larger the molecules, slower will be the rate of diffusion. This is also called Graham's law of diffusion.

$$D \propto \frac{1}{\sqrt{d}} \quad (D = \text{Diffusion and } d = \text{Density of diffusing substance}).$$

According to the density the diffusion of substances takes place in following manner :

$$\text{Gas} > \text{Liquid} > \text{Solid}$$

The vapours of volatile liquids (scent or petrol) and solids (camphor) also diffuse like gases.

**Density of the medium** : The rate of diffusion is slower, if the medium is concentrated. Thus, a gas would diffuse more rapidly in vacuum than in air. Substances in solution also diffuse but at a much slower rate than gases.

**Diffusion pressure gradient (DPG)** : The rate of diffusion is directly proportional to the difference of diffusion pressure at the two ends of a system and inversely proportional to the distance between the two.

#### Significance of diffusion

(1) Gaseous exchange during the processes of photosynthesis and respiration takes place with the help of diffusion.

(2) The process of diffusion is involved in the transpiration of water vapours.

(3) Aroma of flowers is due to diffusion of volatile aromatic compounds to attract pollinating animals.

(4) During passive salt uptake, the ions are absorbed by process of diffusion.

(5) Diffusion helps in translocation of food materials.

(6) Gaseous exchange in submerged hydrophytes takes place by general surface of the cells through diffusion.

**Permeability** : Permeability is the degree of diffusion of gases, liquids and dissolved substances through a membrane. Different types of membranes may be differentially permeable to different substances.

**Types of membranes** : On the basis of permeability.

**Permeable membrane** : These membranes allow free passage of solvent (water) and most of the dissolved substances. e.g., cell wall in plant cells. Filter paper is made up of pure cellulose it also functions as permeable membrane.

**Impermeable membrane** : This type of membranes with deposits of waxy substances like cutin and suberin, do not allow the entry of water, dissolved substances and gases. e.g., suberized walls of cork cells, cuticle layer of leaf.

**Semi-permeable membrane** : These membranes permit the movement of solvent molecules only through them, but prevent the movement of solute particles. e.g., egg membrane, animal bladder, parchment paper, copper ferrocyanide membrane, membranes of collodion.

**Selectively or Differentially permeable membrane** : This type of membranes allow selective passage of solutes along with solvent, through them.

Many biological membranes such as cell membrane (plasmalemma), tonoplast (vacuolar membrane) and the membranes surrounding the sub-cellular organelles are selectively permeable. A non-living selectively permeable membrane is cellophane

**Osmosis** : Osmosis (Gr. Osmos = a pushing or impulse) was discovered by Abbe Nollet in 1748 and also coined the term 'osmosis'. First of all Traube (1867) used copper ferrocyanide and developed semipermeable membrane to show its utility in the osmosis of plant physiology. First time Pfeffer in (1887) developed osmoscope by using semipermeable membrane.

Osmosis is special type of diffusion of a liquid, when solvent moves through a semipermeable membrane from a place of higher diffusion pressure to a place of lower diffusion pressure.

Or

It is the migration of solvent from a hypotonic solution (of lower concentration) to hypertonic solution (of higher concentration) through a semi-permeable membrane to keep the concentration equal

In formalin preserved *spirogyra* filament, selective permeability of plasma membrane is lost and hence no effect on placing in hypertonic solution.

**Reverse Osmosis** : It is the reverse movement of water through a semipermeable membrane from a more concentrated solution to a more dilute solution by applying external pressure on the more concentrated solution.

It is used in removing salts from saline water as well as extra – purification of water.

**Osmotic pressure (OP)** : Pfeffer coined the term osmotic pressure

Osmotic pressure is that equivalent of maximum hydrostatic pressure which is produced in the solution, when this solution is separated from its pure solvent by a semipermeable membrane. Osmotic pressure of a solution is greater than pure solvent.

**Types of osmosis** : Depending upon the movement of water into or outside of the cell, osmosis is of two types.

**Endosmosis** : The osmotic flow of water into a cell, when it is placed in a solution, whose solute concentration is less than that of the cell sap, is called endosmosis e.g., swelling of raisins, when they are placed in water.

When a fish of marine water kept in fresh water then it will die due to endosmosis

An animal cell placed in pure water will swell up and bursts.

Pollen grains of some of plants germinate on stigma soon but they burst in water or dilute sugar solution.

**Exosmosis** : The osmotic outflow of water from a cell, when it is placed in a solution, whose solute concentration is more than that of the cell sap, is called exosmosis. e.g., shrinkage of grapes, when they are placed in strong sugar solution.

#### Osmotic concentrations (Types of solutions)

**Hypotonic solution** (*hypo* = less than). A solution, whose osmotic concentration (solute potential) is less than that of another solution or cell sap is called hypotonic solution. If a cell is placed in such a solution, water starts moving into the cell by the process of endosmosis, and cell becomes turgid.

**Hypertonic solution** (*hyper* = more than). A solution, whose osmotic concentration (solute potential) is more than that of another solution or cell sap is called hypertonic solution. If a cell is placed in such a solution, water comes out of the cell by the process of exosmosis and cell becomes flaccid. If potato tuber is placed in concentrated salt solution it would become shrink due to loss of water from its cell.

**Isotonic solution** (*iso* = the same). A solution, whose osmotic concentration (solute potential) is equal to that of another solution or cell sap, is called isotonic solution. If a cell is placed in isotonic solution, there is no net changes of water between the cell and the solution and the shape of cell remain unchanged.

In xerophytes, the osmotic concentration of cell sap is more than the normal. The osmotic pressure of given solution can be calculated by following formula.

$$\text{Osmotic pressure} = \text{CST}$$

Where, C = Molar concentration of solution, S = Solution constant, which is 0.082 and T = Absolute temperature i.e., 273°K.

#### Significance of osmosis in plants

(1) The phenomenon of osmosis is important in the absorption of water by plants.

(2) Cell to cell movement of water occurs throughout the plant body due to osmosis.

(3) The rigidity of plant organs (i.e., shape and form of organism) is maintained through osmosis.

(4) Leaves become turgid and expand due to their OP.

(5) Growing points of root remain turgid because of osmosis and are thus, able to penetrate the soil particles.

(6) Opening and closing of stomata is affected by osmosis.

(7) Movement of plants and plant parts, e.g., movement of leaflet of Indian telegraph plant.

**Turgor pressure (TP)** : The plant cell, when placed in pure water, swells but does not burst. Because of negative osmotic potential of the vacuolar solution (cell sap), water will move into the cell and will cause the plasmalemma be pressed against the cell wall. The actual pressure that develops that is the pressure responsible for pushing the membrane against cell wall is termed turgor pressure

#### Significance of turgidity in plants

(1) It provides stability to a cell.

(2) Turgidity keeps the cell and their organelles (mitochondria, plastids and microbodies) fully distended. This is essential for plants to live and grow normally.

(3) Turgor pressure helps in cell enlargement, consequently in stretching of the stems and in keeping leaves erect and fully expanded.

(4) The turgid cells provide mechanical support necessary for the non woody tissues (maize, sugarcane, banana etc.).

(5) Loss of turgidity leads to wilting of leaves and drooping of shoots.

(6) The opening and closing of stomata are regulated by the turgidity of the guard cells.

(7) Leaf movements (seismonastic movement) of many plants (such as bean, sensitive plant *Mimosa pudica*) are controlled by loss and gain of cell turgor.

(8) Due to turgor pressure plumule and radicles force out from seeds at the time of seed germination.

**Wall pressure (WP)** : Wall pressure (WP) may, therefore, be defined as 'the pressure exerted by the cell wall over the protoplast to counter the turgor pressure. Normally wall pressure is equal and opposite to turgor pressure ( $WP = TP$ ) except when the cell become flaccid. The value of the two forces continue to rise with the continued entry of water, till the cell becomes fully turgid.

**Interrelationship of DPD (S.P.), OP and TP (WP) :** DPD indicates the sucking power of suction pressure. As water enters into the cell the TP of the cell is increased. Cell wall exerts equal and opposite WP against TP. The actual force responsible for entry of water will be therefore OP-TP

$$\text{i.e., DPD} = \text{OP} - \text{WP} \text{ (As WP} = \text{TP)}$$

$$\text{DPD} = \text{OP} - \text{TP}$$

Consider that a plant cell with OP = 10 atm. is immersed in pure water. In the beginning TP inside the cell is zero i.e.,

$$\text{DPD} = \text{OP} = 10 \text{ atm.}$$

When water enters into the cell, TP increases. Turgidity increases and cell wall develops equal and opposite WP. At the stage of equilibrium TP = 10 atm. and DPD will become zero. It is important to note that OP was same when cell was flaccid and turgid.

$$\text{DPD} = \text{OP} - \text{TP}$$

$$= 10 - 0 = 10 \text{ (when flaccid)}$$

$$= 10 - 10 = 0 \text{ (when turgid)}$$

The entry of water in cell to cell depends upon the DPD and not on OP and TP. This can be exemplified as follows :

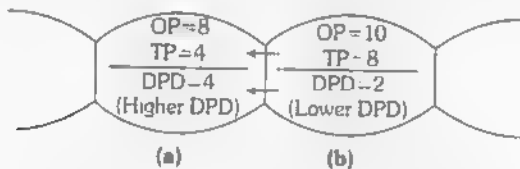


Fig : 4.1-1 Relation between diffusion pressure deficit and entrance of water in the cell

Since the DPD of cell A is more, it has less water and, therefore water would diffuse from cell B into the cell A (because that DPD of cell B is less than that of A or it has more water than cell A has). The entry of water into the cell A would stop when DPD of both the cells become equal. In this way water moves from a cell with less DPD into the cell with more DPD. Thus, DPD is the osmotic parameter, which determines the flow of water from one cell to another.

Under given suitable conditions, the DPD is more than OP when TP is negative.

DPD is maximum in a flaccid cell.

**Plasmolysis (Gr. Plasma = something formed; lysis = loosening) :** "The shrinkage of the protoplast of a living cell from its cell wall due to exosmosis under the influence of a hypertonic solution is called plasmolysis". The stage of plasmolysis, when the protoplast just begins to contract away from the cell wall is called incipient plasmolysis. The stage when the cell wall has reached its limit of contraction and the protoplast has detached from cell wall attaining spherical shape is called evident plasmolysis. If a cell with incipient plasmolysis is placed in a hypertonic solution it will show more plasmolysis.

**Deplasmolysis :** "The swelling up of a plasmolysed protoplast due to endosmosis under the influence of a hypotonic solution or water is called deplasmolysis". Deplasmolysis is possible only immediately after plasmolysis otherwise the cell protoplast becomes permanently damaged. The value of TP becomes zero at the time of limiting plasmolysis and below zero during incipient and evident plasmolysis. Leaf of *Tradescantia* is used for demonstration of plasmolysis in laboratory.

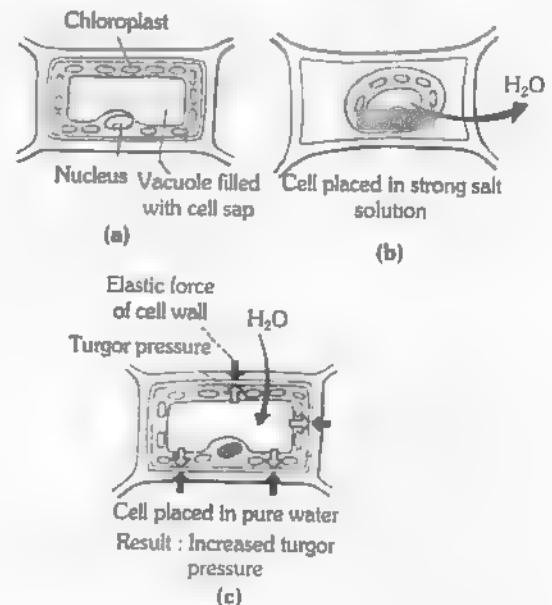


Fig : 4.1-2 Plasmolysis and deplasmolysis  
(a) Normal cell (b) Plasmolysed cell  
(c) Deplasmolysed cell and increased turgor pressure

### Significance of plasmolysis

(1) The OP of a cell can be measured by plasmolysis. The OP of a cell is roughly equal to the OP of a solution that causes incipient plasmolysis in the cell.

(2) Salting of pickles, meat, fishes etc. and addition of sugar to jams, jellies, cut fruits etc., prevent their decay by microbes, as the latter get killed due to plasmolysis or due to high concentration of salt or sugar.

(3) By salting, the weeds can be killed from tennis courts and the growth of plants can be prevented in the cracks of walls.

(4) Plasmolysis is helpful in determining whether a particular cell is living or dead as plasmolysis does not occur in a dead or non living cell.

**Water potential ( $\psi$ ) :** The term water potential was coined by slatyer and Taylor (1960). It is a modern term which is used in placed of D.P.D. The movement of water in plants cannot be accurately explained in terms of difference in concentration or in any other linear expression. The best way to express spontaneous movement of water from one region to another is in terms of the difference of free energy of water between two regions. Free energy is the thermodynamic parameter, that determine the

direction in which physical and chemical changes must occur. The potential energy of water is called water potential. e.g., water is stored behind a dam. When the water runs downhill, its potential energy can be converted to electrical energy. This conversion of energy of water is due to gravity. The other source that provides energy to water is pressure. The increasing pressure increases the free energy there by increasing water potential.

Water running downhill due to gravity can be made to run uphill by overcoming the water potential (energy) by applying pressure. This means that water moves from the point, where water potential is greater to the other, where water potential is less. The difference in water potential between two points is a measure of the amount of work or energy needed to move water from one point to the other. Thus, based on the concept of water potential, the direction of water movement can be predicted. Water potential is measured in terms of pressure.

Measurement unit of water potential is pascal, Pa (1 mega pascal, Mpa = 10 bars). It is represented by Greek letter, Psi ( $\psi$ ). Water potential ( $\psi_w$ ) is the difference between chemical potential of water at any point in a system ( $\mu_w$ ) and that of pure water under standard conditions ( $\mu_w^\circ$ ). The value of water potential can be calculated by formula :

$$\psi_w = (\mu_w) - (\mu_w^\circ) = RT \ln e/e^\circ$$

where  $\psi_w$  = water potential, R is gas constant, T is absolute temperature (K),  $e$  is the vapour pressure of the solution in the system at temperature T, and  $e^\circ$  the vapour pressure of pure water at the same temperature.

The direction in which water will move from one cell to another cell depends on water potential in two regions. Water potential is measured in bars. A bar is a pressure unit which equals 14.5 lb/in<sup>2</sup>, 750 mm Hg or 0.987 atm.

Water potential of pure water at normal temperature and pressure is zero. This value is considered to be the highest. The presence of solute particles reduces the free energy of water and thus decreases the water potential. Therefore, water potential of a solution is always less than zero or has negative value.

**Component of water potential :** The water potential ( $\psi$ ) in a plant cell or tissue can be written as the sum of the matric potential ( $\psi_m$ ) due to binding of water to cell walls and cytoplasm, the solute potential ( $\psi_s$ ) due to concentration of dissolved solutes, which by its effect on the entropy components reduces the water potential and the pressure potential ( $\psi_p$ ) due to hydrostatic pressure, which by its effect on the energy components increases the water potential :

$$\psi = \psi_m + \psi_s + \psi_p \quad \dots\dots (1)$$

**Matric potential ( $\psi_m$ ) :** Matric is the term used for the surface (such as, soil particles, cell walls, protoplasts, etc.) to which water molecules are adsorbed. The matric potential ( $\psi_m$ ) is the component of water potential influenced by the presence of a matrix. It has got a negative value. In case of plant cells and tissues, the matric potential is often disregarded because it is not significant in osmosis. Thus, the above equation (1) may be simplified as follows :

$$\psi = \psi_s + \psi_p \quad \dots\dots (2)$$

In normal cells of mesophytes and hydrophytes it is almost negligible.

**Solute potential ( $\psi_s$ ) :** Solute potential is also known as *Osmotic potential*. It is defined as the amount by which the water potential is reduced as a result of the presence of solute. Solute potentials or osmotic potentials ( $\psi_s$ ) are always in negative values (number). The term solute potential takes the place of osmotic pressure ( $\pi$ ;  $\Pi$ ) expressed in bars with a negative sign.

$$\psi_s = -\pi$$

**Pressure potential ( $\psi_p$ ) :** Plant cell wall is elastic and it exerts a pressure on the cellular contents. As a result of inward wall pressure, hydrostatic pressure is developed in the vacuole termed as turgor pressure. The pressure potential is usually positive and operates in plant cells as *wall pressure* and *turgor pressure*.

Its magnitude varies between +5 bars (during day) and +15 bars (during night).

**Physical states of cell :** Three physical states of cell, according to their water potential, are as follows :

**In case of fully turgid cell :** In case of fully turgid cell, the net movement of water into the cell is stopped. The cell is in equilibrium with the water outside. The water potential in such a case will be zero (0)

Water potential = Osmotic potential + Pressure potential

$$\psi = \psi_s + \psi_p$$

A cell at full turgor has its osmotic potential and pressure potential equal but opposite in sign. Therefore, its water potential will be zero. For example, supposing a cell has its  $\psi_s$  of -10 bars and  $\psi_p$  of 10 bars the resultant water potential will be zero as follows :

$$\psi = \psi_s + \psi_p$$

$$\psi = -10 \text{ bars} + 10 \text{ bars}$$

$$\psi = 0 \text{ bars}$$

**In case of flaccid cell :** When a plant cell is flaccid, its turgor becomes zero (corresponding to a turgor pressure of 0 bars). Zero turgor is approached under natural conditions when a tissue is severely wilted. A cell at zero turgor has an osmotic potential ( $\psi_s$ ) equal to its water potential ( $\psi$ ). For example, supposing a flaccid cell has an osmotic potential of -10 bars and pressure potential ( $\psi_p$ ) of 0 bars.

Water potential = Osmotic potential + Pressure potential

$$\psi = \psi_s + \psi_p$$

$$\psi = -10 \text{ bars} + 0 \text{ bars}$$

$$\psi = -10 \text{ bars}$$

The water potential of the cell will be -10 bars, which is less as compared to the water potential of pure water (0 bars)

**In case of plasmolysed cell :** When the vacuolated parenchymatous cells are placed in solutions of sufficient strength the protoplast decreases in volume to such an extent that they shrink away from the cell wall. The cells are plasmolysed. Such cells have negative value of pressure potential (negative turgor pressure). The resultant water potential will be more negative, as for example, a plasmolysed cell has osmotic potential of -10 bars and pressure potential of -2 bars the water potential of the cell will be -12 bars.

Water potential = Osmotic potential + Pressure potential

$$\psi = \psi_s + \psi_p$$

$$\psi = -10 + (-2)$$

$$\psi = -12 \text{ bars}$$

#### Movement of water between two adjacent cells :

Suppose A and B are two adjacent plant cells where osmotic movement of water can occur. Cell A has osmotic potential ( $\psi_s$ ) of -16 bars and pressure potential of 8 bars. The cell B has osmotic potential of -12 bars and pressure potential of 2 bars. The movement of water will be as follows :

Cell A	Cell B
$\psi_s = -16$ $\psi_p = 8$	$\psi_s = -12$ $\psi_p = 2$
$\psi = \psi_s + \psi_p$ $= -16 + 8 = -8$	$\psi = \psi_s + \psi_p$ $= -12 + 2 = -10$

**Wilting** : A plant usually fails to survive if it is conditioned to water deficiency. The symptoms appear in the plant, plant parts or in the cells due to scarcity of water are termed as wilting. It is loss of turgidity causing folding and drooping of leaves and other soft aerial parts of the plant. It is of three types :

(1) **Incipient wilting** : There is no external symptoms but the mesophyll cells lose a part of their water content during midday due to transpiration.

(2) **Temporary wilting** : It occurs during midday and is visible externally due to drooping of leaves and young shoots. At noon the rate of transpiration is quite high as compared to water absorption, which decreases further due to depletion of water around rootlets. It is corrected in the afternoon when transpiration decreases.

(3) **Permanent wilting** : It is the last stage in wilting when the aerial parts do not regain turgidity even if placed in water saturated atmosphere. It is caused by decrease in water content of the soil which increases TSMS (Total soil moisture stress) or resistance to absorption to such an extent that plant roots are unable to absorb water. Permanent Wilting Percentage (PWP) is the percentage of water on the dry weight basis of the soil that is present in the soil when the plants growing in it first touch the condition of permanent wilting. This value varies between 1-15% and depends upon the texture of the soil e.g., clay has higher PWP than sand.

### Absorption of water

Water is absorbed from soil by root system and specially by younger parts (i.e., root tips). In higher plants water is absorbed through root hairs.

**Soil water** : The chief source of soil water is rain. In soil water is found in different forms. The total amount of water present in the soil is called holard, of this the available to the plant is called chresard and the water which cannot be absorbed by the plants is called echard.

Water occurs freely deep in the soil and above the parent rock, it is called ground water. These are briefly described below :

**Gravitational water** : When the water enters the soil and passes the spaces between the soil particles and reaches the water table, the type of soil water is called gravitational water.

**Capillary water** : It is the water which is held around soil particles in the capillary space present around them due to force like cohesion and surface tension. This is the water which can be utilised by the plants. It is also called growth water. It occurs in the form of films coating smaller soil particles.

The availability of capillary water to the plant depends upon its diffusion pressure deficit which is termed as the soil moisture stress. The plant cells have a DPD much more than the soil moisture stress for proper absorption of water.

**Hygroscopic water** : This is the form of water which is held by soil particles of soil surfaces. The water is held tightly around the soil particles due to cohesive and adhesive forces. Cohesive and adhesive forces greatly reduce the water potential ( $\psi_w$ ) and thus this type of water in soil is not available to plants.

**Run-away water** : After the rain, water does not enter the soil at all, but drained off along the slopes. It is called run-away water. Plants fail to avail this water.

**Chemically combined water** : Some of the water molecules are chemically combined with soil minerals (e.g., silicon, iron, aluminium, etc.). This water is not available to the plants.

**Water vapour** : That portion of the pore space in a soil which is not occupied by liquid water contain a soil atmosphere that always includes water vapour.

**Water holding capacity** : The amount of water actually retained by the soil is called field capacity or water holding capacity of the soil. It is about 25-35% in common loam soil. The excess amount of water beyond the field capacity produces water logging.

**Soil atmosphere** : In moderately coarse soils as well as in heavy soils (fine textured soil) that are with aggregated particles; there exists large interstitial spaces which facilitate the diffusion of gases. As a result the  $\text{CO}_2$  produced in a soil by respiration of soil organisms and roots is able to escape rather easily and oxygen used up in this process diffuses into the soil with corresponding case.

**Water absorbing organs** : Plants absorb water mostly from the soil by their roots, but in some plants even aerial parts like stem and leaves also do the absorption of atmospheric water or moisture. Some important examples of such plants are *Vitis*, *Solanum*, *Lycopersicon*, *Phaseolus*, *Kochia baasia* and *Beta*.

However, maximum absorption of water is done by the roots.

This area is usually characterized by the presence of root hairs which serve to increase the area of contact between the root surface and soil.

The root hairs develop mainly at the tip just above the zone of elongation (cell maturation). A root hair is the unicellular tubular prolongation of the outer wall of the epiblema.

During water absorption the plasma membrane of root hair, the cytoplasm and the vacuole membrane (tonoplast) behave together as a single differentially permeable membrane. Root hairs are at the most 1.25 cm in length and never more than 10 mm in diameter.

The root-hairs of plants increase the absorption surface of a root system about 5 to 20 times and because they extend so widely through the soil they make available a supply of water that the plant could not otherwise obtain. Water potential of root hair cells is generally  $-1$  to  $-4$  atm.

**Pathway of water movement in root :** Water in the root moves through three pathways. Munch coined the term apoplast and symplast.

**Apoplast pathway :** The apoplastic movement of water occurs exclusively through the cell wall without crossing any membrane.

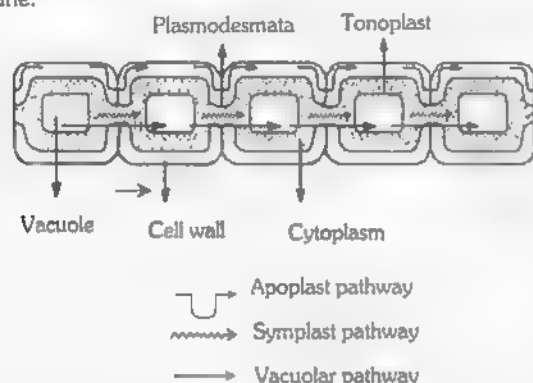


Fig : 4.1-3 Three pathways of water movement

**Symplast pathway :** The symplastic movement of water occurs from cell to cell through the plasmodesmata.

**Transmembrane pathway :** Water after passing through cortex is blocked by casparian strips present on endodermis. The casparian strips are formed due to deposition of wax like substance, suberin. In this pathway, water crosses atleast two membranes from each cell in its path. These two plasma membranes are found on entering and exiting of water. Here, water may also enter through tonoplast surrounding the vacuole i.e., also called as vacuolar pathway.

**Mechanism of water absorption :** Two distinct mechanisms which are independently operated in the absorption of water in plants. These mechanisms are :

- (1) Active absorption (2) Passive absorption

Renner (1912, 1915) coined the term active and passive water absorption.

(1) **Active absorption :** Active absorption takes place by the activity of root itself, particularly root hairs. The factor responsible for water absorption is present within the roots. It utilizes metabolic energy. There are two theories of active absorption :

**Osmotic theory :** It was proposed by Atkins (1916) and Priestley (1922). It is purely a physical process, which does not directly require expenditure of energy.

A root hair cell functions as an osmotic system. Water is absorbed by the root hair due to osmotic differences between soil water and cell sap. The osmotic pressure of soil water remains below 1 atm, but that of cell sap is usually 2-8 atm. Thus, there exists a great difference in the osmotic pressures of the two sides or in other words there exists, water potential gradient between the soil solution and cell sap. The soil solution having less OP, has higher water potential than the cell sap with more OP (i.e., the cell

sap has more negative water potential). Thus, water moves from the region of higher water potential towards the region of lower water potential.

**Non-osmotic theory :** It was proposed by Thimann (1951) and Kramer (1959). It has been observed that absorption of water still occurs, if the concentration of cell sap in the root hair is lower than that of the soil water, or water is absorbed against concentration gradient (i.e., from higher DPD to lower DPD). Such type of water absorption occurs on the expense of energy obtained from respiration.

Following evidences support the view that energy is utilized during active absorption of water :

(i) Rate of water absorption is directly proportional to the rate of respiration.

(ii) Respiratory inhibitors such as KCN, which inhibit the absorption of water.

(iii) Auxins (growth hormones), which increase respiration also promote water absorption

(iv) Wilting of plants occur in non-aerated soils such as water logged soils, as roots fail to absorb water in absence of respiration.

(2) **Passive absorption :** It is the most common and rapid method of water absorption. The factor responsible for water absorption is present somewhere else than roots. It accounts for about 98% of the total water uptake by plant.

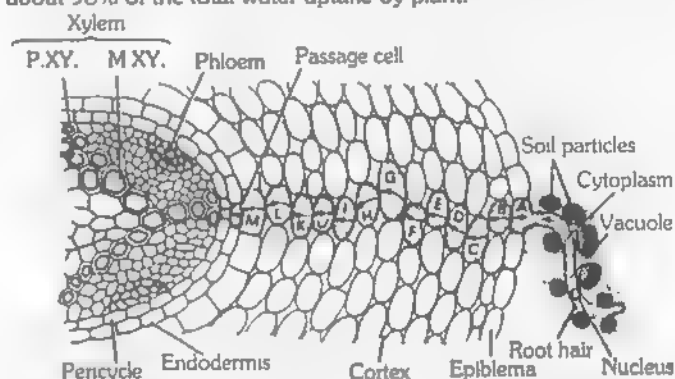


Fig : 4.1-4 Passive absorption of water through root hair

According to this theory, the forces responsible for absorption of water originate not in the cells of roots but in the cells of transpiring shoots. The root cells remain passive.

Due to transpiration, the DPD of mesophyll cells in the leaves increases which causes absorption of water by these cells from the xylem vessels of leaves. As the water column is continuous from leaves to roots, this deficit is transmitted to the xylem elements of roots and finally to root hairs through pericycle, endodermis and cortex. In this way water is continuously absorbed due to transpiration pull created in the leaves. This type of water transport occurs mainly through the apoplast in cortex but through the symplast in endodermis and pericycle.

The path of water from soil upto secondary xylem is :

Soil  $\rightarrow$  Root hair cell wall  $\rightarrow$  Cortex  $\rightarrow$  Endodermis  $\rightarrow$  Pericycle  $\rightarrow$  Protoxylem  $\rightarrow$  Metaxylem.

**Factors affecting rate of water absorption :** The different factors which influence the rate of water absorption by a plant can be divided into external or environmental and the internal factors.

**External or Environmental factors**

**The amount of soil water :** It is optimum at field capacity. Water absorption decreases above it. It begins to decline and stops at PWP

**Concentration of the soil solution :** If the concentration of solutes increases in the soil water, its OP also increases which slows down or even inhibits the absorption of water. It happens due to addition of enough fertilizers in the soil increasing its salinity. This is popularly called as physiological dryness.

**Soil aeration :** Water absorption is done more efficiently in well aerated soil. Any deficiency of oxygen stops the respiration of roots and causes accumulation of  $\text{CO}_2$  thus the protoplasm becomes viscous and the permeability of plasma membrane decreases. Due to all these factors the rate of water absorption is reduced. This is the reason for death of plants in flooded areas.

**Soil temperature :** The optimum temperature for maximum rate of water absorption ranges between  $20^\circ\text{C}$  and  $30^\circ\text{C}$ . Too high temperature kills the cells. At very low temperatures ( $4^\circ\text{C}$ ) water absorption is reduced or stopped and about  $0^\circ\text{C}$  it is almost checked.

**Transpiration :** The rate of absorption of water is almost directly proportional to the rate of transpiration. A higher rate of transpiration increases the rate of water absorption.

**Internal factors**

**Efficiency of the root system :** A plant with deep and elaborate root system can absorb more water. The number of root hairs will be more in a highly branched and elaborate root system, thus its more surface area will be in contact with water.

In gymnosperms, the root hairs are absent, even then they are able to absorb water due to presence of mycorrhizal hyphae.

In epiphytes (orchid), the roots develop a special type of hygroscopic tissue called as velamen which can absorb atmospheric moisture.

**Metabolic activity of roots :** The poor aeration or use of metabolic inhibitors (e.g., KCN) inhibits the rate of water absorption. The metabolic activities help in proper growth of root system and generation of energy for absorption of certain vital minerals.

**Absorption of water through leaves :** Many species of plants can absorb atleast limited amounts of water through the leaves. Temporary immersion of aerial organs in flood waters takes place in some cases. Also the aerial organs of plants frequently become wet as a result of fog, dew or rain. Most of the water enters through the epidermal cells, although in some species hairs and specialized epidermal cells provide regions of high permeability. In general water absorption is more rapid in young leaves than in old leaves of the same plant.

**Ascent of sap**

The upward transport of water along with dissolved minerals from roots to the aerial parts of the plant is called 'Ascent of sap'. It is also called translocation of water. The water with dissolved minerals is called sap.

**Path of ascent of sap :** It is now well established that the ascent of sap takes place through xylem. In herbaceous plants almost all the tracheary elements participate in the process, but in large woody trees the tracheary elements of only sap wood are functional. Further, it has been proved experimentally that sap moves up the stem through the lumen of xylem vessels and tracheids and not through their walls.

**Theories of ascent of sap :** The various theories put forward to explain the mechanism of ascent of sap in plants can be placed in following three categories :

- (1) Vital force theories
- (2) Root pressure theory
- (3) Physical force theories

**(1) Vital force theories :** According to these theories the forces required for ascent of sap are generated in living cells of the plant. These theories are not supported by experimental evidences hence they have been discarded. Some of the important vital force theories are mentioned below :

**According to Westermaier (1883),** ascent of sap occurs through xylem parenchyma; tracheids, and vessels only act as water reservoirs.

**Relay pump theory (Clambering theory) :** According to Godlewski (1884) ascent of sap takes place due to rhythmic change in the osmotic pressure of living cells of xylem parenchyma and medullary rays and are responsible for bringing about a pumping action of water in upward direction. Janse (1887) supported the theory and showed that if lower part of the shoot is killed upper leaves were affected.

**Criticism**

(i) Strasburger (1891) and Overton (1911) used poisons (like picric acid) and excessive heat to kill the living cells of the plant. When such twigs were dipped in water, ascent of sap could still occur uninterrupted. This definitely proved that no vital force is involved in ascent of sap.

(ii) Xylem structure does not support the Godlewski's theory. For pumping action living cells should be in between two xylem elements and not on lateral sides as found.

**Pulsation theory :** Sir J.C. Bose (1923) said that living cells of innermost layer of cortex, just outside the endodermis are in rhythmic pulsations. Such pulsations are responsible for pumping the water in upward direction. According to Bose, the pulsatory cells pump the water into vessels.

**Criticism :** Dixon failed to verify the results of Bose. It has been estimated that sap should flow through 230–240 pulsating cells per second to account for normal rate of pulsations. This rate is several times higher as would be possible to the Bose theory (Shull, MacDougal, Benedict).

**(2) Root pressure theory :** It was proposed by Priestley (1916). According to this theory the water, which is absorbed by the root-hairs from the soil collects in the cells of the cortex. The cortical cells become fully turgid. In such circumstances the elastic walls of the cortical cells, exert pressure on their fluid-contents and force them towards the xylem vessels. Due to this loss of water these cortical cells become flaccid, again absorb water, become turgid and thus again force out their fluid contents. Thus the cortical cells of the root carry on intermittent pumping action, as a result of which considerable pressure is set up in the root. This pressure forces water up the xylem vessels. Thus the pressure, which is set up in the cortical cells of the roots due to osmotic action, is known as the root pressure. This term was used by Stephan Hales. According to Style, root pressure may be defined as "the pressure under which water passes from the living cells of the root in the xylem".



### Objections

(i) Taller plants like *Eucalyptus* need higher pressure to raise the water up. While the value of root pressure ranges from 2-5 atmospheres, a pressure of about 20 atm. is required to raise the water to tops of tall trees.

(ii) The absence of root pressure, ascent of sap continues.

(iii) Plants growing in cold, drought or less aerated soil, root pressure fails to appear and transport of water is normal.

In gymnosperms root pressure has rarely been observed.

(3) **Physical force theories** : According to these theories the ascent of sap is purely a physical process. Some of the physical force theories are mentioned below :

**Capillary force theory** : It was proposed by Boehm (1809). According to him, in the fine tubes, the water rises as a result of surface tension to different heights depending on the capillarity of the tube. The finer the tube, the greater will be the rise of water in it. But the xylem vessels are sometimes broader than the capillarity range, and hence the rise due to surface tension will be negligible.

### Objections

(1) For capillarity a free surface is required.

(2) Atmospheric pressure can support a column of water only upto the height of 34 feet.

(3) Water can rise only upto the height of one meter in xylem vessels having diameter of 0.03mm.

(4) In gymnosperms usually the vessels are absent.

**Imbibitional theory** : It was proposed by Unger (1868) and supported by Sachs (1879). According to them, water moves upward in the stem through the walls of the xylem vessels. This theory is not accepted now because it is proved that water moves through the lumen of the xylem vessels and tracheids.

**Atmospheric pressure theory** : Due to the loss of water by transpiration, the leaves draw water from the xylem vessels through osmotic pressure. The atmospheric pressure acting on the water in the soil forces the water to rise up in the xylem vessels to fill the vacuum. But the atmospheric pressure can force the water to a height of only 10 meters. So it is evident that atmospheric pressure alone cannot force water to a height of 100 metres or more.

**Jamin's chain theory** : In xylem, water and air bubbles are found alternately. Thus upward movement occurs.

**Cohesion of water and transpiration pull theory** : This is the most widely accepted theory put forth by Dixon and Jolly in 1894, and further supported by Renner (1911, 1915), Curtis and Clark (1951), Bonner and Golston (1952), Kramer and Kozlowski (1960).

It is also known as Dixon's cohesion theory, or cohesion-tension theory.

This theory depends on the following assumptions :

(1) The xylem vessels are connected with each other, thus the water in them is in a continuous column from the root hairs to the mesophyll cells.

Walls of tracheids and vessels of xylem are made up of lignin and cellulose and have strong affinity for water (adhesion). The cell wall of adjacent cells, and those between the cells and xylem vessels all through the plant do not affect the continuity of the water column.

(2) Due to the transpiration from leaves, a great water deficit takes place in its cells. As a result of this deficit the water is drawn osmotically from the xylem cells in leaf veins, and by the cells surrounding the veins. Thus a sort of pull is produced in the uppermost xylem cells in the leaves. It is called as the transpiration pull.

(3) The water molecules have a great mutual attraction with each other or in other words we can say that they have tremendous cohesive power which is sometimes as much as 350 atmospheres. Thus the transpiration pull develops a negative pressure in the uppermost xylem cells. It is transmitted from there into the xylem of stems, and from there to the roots.

In this way the water rises due to the transpiration pull and the cohesive power of water molecules from the lowest parts of the roots to the highest peaks of the trees. The osmotic pressure in the transpiring leaf cells often reaches to 30 atmospheres whereas only 20 atmospheres are needed to raise the water to the tops of highest known trees.

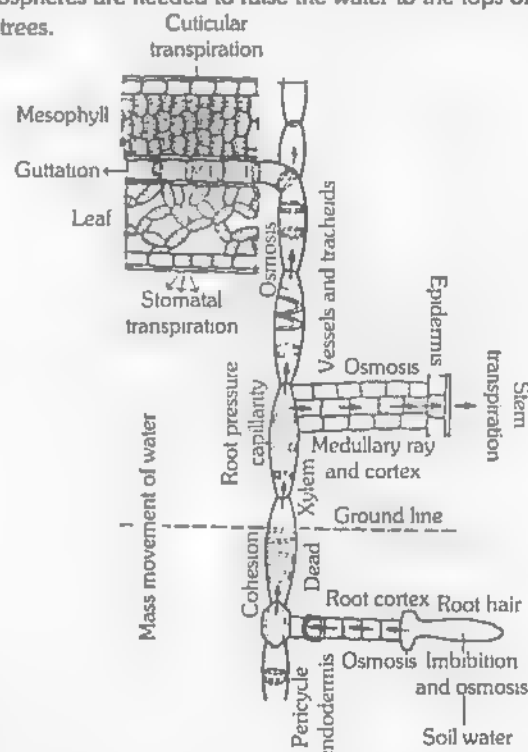


Fig : 4.1-5 Path of ascent of sap showing transpiration pull

**Objections** : This is the most generally accepted theory, yet there are some objections against it which it fails to explain.

The most important objection is that leaving smaller plants, the water column has been found to contain air bubbles, and so their continuity breaks at such places. This phenomenon is known as cavitation and has been demonstrated by Milburn and Johnson (1966). However, Scholander overruled this problem by suggesting that continuity of water column is maintained due to presence of pits in the lateral walls of xylem vessels.

**Velocity of ascent of sap** : Huber and Schmidt (1936) calculated the velocity of ascent of sap using radioactive  $^{32}\text{P}$ , specific dyes and also by heat-pulse transport between two specific points of stem. It varies between 1 and 6 meters per hour but under high transpirational conditions, it may be as high as 45 meters per hour. It is more in ring porous woods having large vessels. It is slowest in gymnosperms.



## Transpiration

"The loss of water in the form of vapours from the aerial parts of a plant is called transpiration". Maximum transpiration occurs in mesophytic plants.

About 98 percent of the water absorbed by land plants evaporates from the aerial parts and diffuse into the atmosphere.

Table : 4.1-1

### Differences between transpiration and evaporation

S.No.	Transpiration	Evaporation
(1)	It is a physiological process and occurs in plants.	It is a physical process and occurs on any free surface.
(2)	The water moves through the epidermis with its cuticle or through the stomata	Any liquid can evaporate. The living epidermis and stomata are not involved
(3)	Living cells are involved.	It can occur from both living and non-living surfaces.
(4)	Various forces (such as vapour pressure, diffusion pressure, osmotic pressure, etc) are involved.	Not much forces are involved
(5)	It keeps the surface of leaf and young stem wet and protects from sun burning.	It causes dryness of the free surface.

(1) **Magnitude of transpiration** : A tropical palm under well watered conditions may lose as much as 500 litres of water per day. Daily loss of water by an apple tree may be 10-20 litres. A maize plant may lose 3-4 litres of water per day.

(2) **Types of transpiration** : Most of the transpiration takes place through the leaves. It is called foliar transpiration. Stems transpire very little. Transpiration from stem is called cauline transpiration. Transpiration is of four types –

(i) **Cuticular transpiration** : Cuticle is a layer of wax like covering on the epidermis of leaves. If it is thin, upto 20 percent of the total transpiration may take place through it, but with the increase in its thickness (e.g., in xerophytes), the water vapour loss is reduced.

(ii) **Lenticular transpiration** : Loss of water vapours through lenticels is called lenticular transpiration. It amounts to about 0.1 percent of the total water loss through transpiration.

(iii) **Stomatal transpiration** : The loss of water vapour, which occurs through specialized pores on leaf surface (stomata) is called stomatal transpiration. It amounts 80-90 percent of the total water vapour loss from the plants. It is the most common type of transpiration.

(iv) **Bark transpiration** : This type of transpiration occurs through corky covering of the stems. Bark transpiration is very little but its measured rate is often more than lenticular transpiration due to larger area. The amount is 0.5% of the total transpiration.

(3) **Structure of stomata** : Stomata are the microscopic openings most commonly found in the leaves. These may be present in young stems and sometimes even in fruits (e.g., citrus, banana, cucumber, etc.). Each stomatal opening is surrounded by two specialized epidermal cells, called as the guard cells.

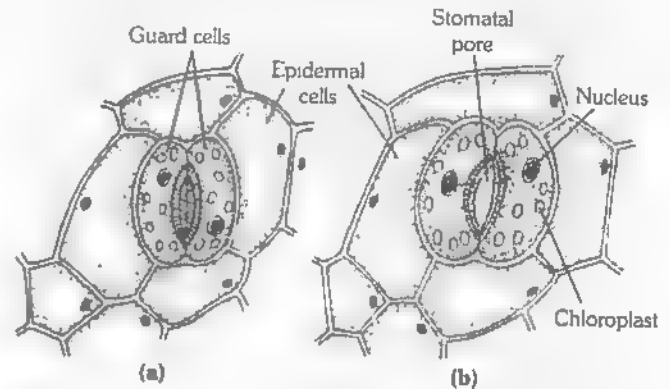


Fig : 4.1-6 Stomatal apparatus (a) Closed (b) Open

Because of their small size, the guard cells are rapidly influenced by turgor change and thus regulate the opening and closing of stomata. The guard cells of dicot leaves are kidney-shaped or reniform whereas those of monocots (family Gramineae) are dumbel-shaped or elliptical. The guard cells are surrounded by epidermal cells called as the accessory cells or subsidiary cells. These are different from the normal cells of epidermis having chloroplasts. These are also different from other cell as these develop from same cell from which guard cells develop. The stoma with subsidiary cells is called stomatal apparatus. Each stoma leads into a air space called sub stomatal cavity. Each guard cell has a thin layer of cytoplasm along the cell wall and a large vacuole. Its cytoplasm contains a distinct nucleus and several chloroplasts. The cell wall of guard cells around the stomatal pores are thickened and elastic due to presence of a secondary layer of cellulose.

The average length of stomata is 20–28 $\mu$ m and breadth 3–10 $\mu$ m. The size of stomatal pore varies from species to species for example of fully opened stomatal pore of *Zea mays* measures 26 $\mu$ m long and 4 $\mu$ m wide.

(4) **Number of stomata on leaves** : The number of stomata is not equal on both surface of leaves in different plants. Number of stomata per square cm is 1,000–60,000 or 10–600/mm<sup>2</sup> in different plants sps.

(5) **Types of stomata** : On the basis of orientation of subsidiary cells around the guard cells, Metcalfe and Chalk classified stomata into following types :

**Anomocytic** : The guard cells are surrounded by a limited number of unspecialized subsidiary cells which appear similar to other epidermal cells. e.g., in Ranunculaceae family.

**Anisocytic** : The guard cells are surrounded by three subsidiary cells, two of which are large and one is very small. e.g., in Solanaceae and Cruciferae families.

**Paracytic** : The guard cells are surrounded by only two subsidiary cells lying parallel to the guard cells e.g., Magnoliaceae family.

**Diacytic** : The guard cells are surrounded by only two subsidiary cells lying at right angles to the longitudinal axis of the guard cells. e.g., Acanthaceae and Labiatae families.

**Actinocytic** : The guard cells are surrounded by four or more subsidiary cells and which are elongated radially to stomata.

(6) **Distribution of stomata** : The stomata differ in their distribution on the two surfaces of the leaf. The leaves are classified into following types on the basis of stomatal distribution on them :

**Epistomatic (Water Lily type)** : Stomata are present only on the upper epidermis of leaves. These are found in water Lily, Nymphaea and many other floating hydrophytes.

**Hypostomatic (Apple or Mulberry type)** : Stomata are present only on the lower surface of leaves. e.g., Apple, mulberry, peach and walnut.

**Amphistomatic** : Stomata are present on both the surfaces of leaves. It can further be subdivided into two types :

(i) **Anisostomatic (Potato type)** : The number of stomata is more on the lower surface and less on the upper surface. In other words, the lower surface is multistomatic and the upper surface is paucistomatic. Such leaves are also called as dorsiventral leaves. e.g., Potato, tomato, bean, pea, and cabbage.

(ii) **Isostomatic (Oat type)** : The stomata are equally distributed on both the surfaces of leaves. These leaves are also called as isobilateral leaves. These are found in monocots e.g., Oat, maize, grasses, etc.

**Astomatic (Potamogeton type)** : Stomata are either absent altogether or vestigial. e.g., Potamogeton and submerged hydrophytes.

(7) **Daily periodicity of stomatal movement** : Loftfield (1921) classified the stomata into four types, depending upon the periods of opening and closing.

**Alfalfa type (Leuceme type)** : The stomata remain open throughout the day but close during night, e.g., Pea, bean, mustard, cucumber, sunflower, radish, turnip, apple, grape.

**Potato type** : The stomata close only for a few hours in the evening, otherwise they remain open throughout the day and night e.g. Cucurbita, Allium, Cabbage, Tulip, Banana etc.

**Barley type** : These stomata open only for a few hours in the day time, otherwise they remain closed throughout the day and night, e.g., Cereals.

**Equisetum type** : The stomata remain always open throughout the day and night. e.g., Amphibious plants or emergent hydrophytes.

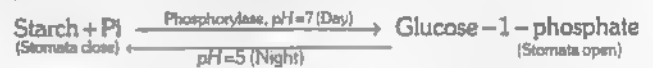
(8) **Mechanism of opening and closing of stomata (Stomatal movement)** : Opening and closing of stomata occurs due to turgor pressure changes in guard cells. The transpiration is regulated by the movement of guard cells of stomata.

Several theories have been put forth to explain the opening and closure of stomata. Which have been discussed below :

**Photosynthetic theory** : According to Von Mohl (1856) the chloroplasts present in guard cells prepare osmotically active substances by photosynthesis. As a result, their osmotic pressure increases and their turgor pressure increases due to endosmosis. This results in opening of stomata.

**Objection** : In many cases, chloroplasts of guard cells are poorly developed and incapable of performing photosynthesis.

**Starch = sugar interconversion theory** : According to Lloyd (1908), turgidity of guard cell depends upon interconversion of starch and sugar. This fact was supported by Loftfield (1921) who found that guard cells contain sugar during day time when they are open and starch during night when they are closed. Later Sayre (1926) observed that stomata open in neutral or alkaline pH which prevails during day time due to constant removal of  $\text{CO}_2$  by photosynthesis. They remain closed during night when there is no photosynthesis and due to accumulation of  $\text{CO}_2$ , carbonic acid is formed which causes the pH to be acidic. Sayre thus proposed that interconversion of starch and sugar is regulated by the pH. Sayre's hypothesis was supported by Scarth (1932) and Small et al (1942). This hypothesis was further supported by detection of the enzyme phosphorylase in guard cells by Yin and Tung (1948). This enzyme is responsible for starch-glucose interconversion.



#### Criticism

(1) Starch = Sugar interconversion is a slow process which can not account for rapid stomatal movement.

(2) Starch or other polymerised polysaccharide do not occur in onion plant where stomatal movement occurs.

(3) Glucose is not detectable in the guard cells when stomatal opening occurs.

(4) The theory could not explain the extra-effectiveness of blue light at the time of stomatal opening.

**Stewards modification** : Steward (1964) said that glucose-1-phosphate should be further converted into glucose as glucose-1-phosphate is not capable of changing osmotic pressure. In this process of stomatal opening and closing, enzymes like phosphorylase, phosphoglucomutase, phosphatase and hexokinase are present in guard cells

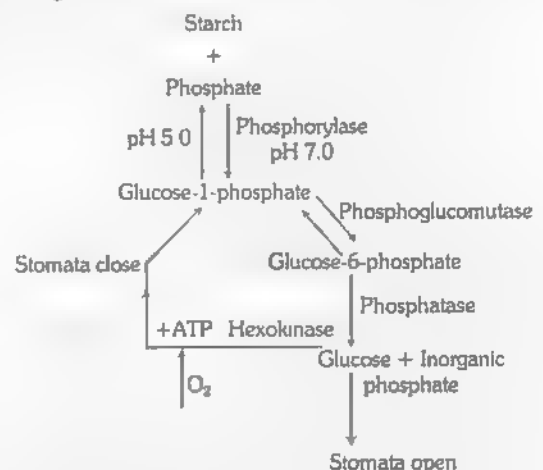


Fig : 4.1-7 Mechanism of opening and closing of stomata according to Steward

**Glycolate theory** : Zelitch (1963) proposed that stomata open due to production of glycolic acid by photorespiration in guard cells under low concentration of  $\text{CO}_2$ . The glycolic acid thus produced is converted into soluble carbohydrates which increase the O.P. of guard cells

### **Stomatal opening in succulent plants (Scotoactive**

**stomata)** : The stomata in succulent plant or CAM plants (like *Opuntia*, *Bryophyllum* etc.) open during night (darkness) and remain closed during the day time and found in lower surface. This type of stomatal opening is called 'Scotoactive type' and the stomata which open during day are called as photoactive. Stomata closed and open due to the activity of water. This type of stomata is known as hydroactive stomata. The opening and closing mechanism of scotoactive stomata was explained by Nishida (1963). In succulent plants, during night, there is incomplete oxidation of carbohydrates and accumulation of organic acids (e.g., malic acid) without release of  $\text{CO}_2$ . During day time the accumulated organic acids breakdown rapidly releasing excess amount of  $\text{CO}_2$  for photosynthesis as well as to keep the stomata closed.



Transpiration depends upon difference in vapour pressure of internal atmosphere of leaf and external environment (i.e., V.P. gradient) and it is therefore, that no transpiration occurs when stomata are fully open but relative humidity is 100%.

(6) The guard cells become flaccid and the stomata close.

**Internal factors/Plant factors**

**Leaf area :** If leaf area is more, transpiration is faster. However, the rate of transpiration per unit area is more in smaller leaves than in larger leaves due to high number of stomata in a small leaf. Number of stomata per unit area of leaf is called stomatal frequency.

$$I = \frac{S}{E + S} \times 100 \text{ here, } I = \text{Stomatal index}$$

$S$  = No. of stomata per unit area

$E$  = No. of epidermal cells in unit area.

**Leaf structure :** The anatomical features of leaves like sunken or vestigial stomata; presence of hair, cuticle or waxy layer on the epidermis; presence of hydrophilic substances such as gums, mucilage etc. in the cells; compactly arranged mesophyll cells etc. help in reducing the rate of transpiration.

**Root shoot ratio :** According to Parker (1949) the rate of transpiration is directly proportional to the root-shoot ratio.

**Age of plants :** Germinating seeds show a slow rate of transpiration. It becomes maximum at maturity. However, it decreases at senescence stage.

**Orientation of leaves :** If the leaves are arranged transversely on the shoot they lose more water because they are exposed to direct sunlight. If placed perpendicularly they transpire at slower rate.

**Significance of transpiration :** The advantages and disadvantages of transpiration are discussed below :

**Advantages**

- (1) Transpiration is important for plants because it directly influences the absorption of water from the soil.
- (2) Transpiration exerts a tension or pull on water column in xylem which is responsible for the ascent of sap.
- (3) Transpiration helps in the movement of water and minerals absorbed by the roots to the other parts of the plant.
- (4) The evaporation of water during transpiration contributes to the cooling of leaves (and also the surrounding air) and protects leaves from heat injury particularly under conditions of high temperature and intense sunlight.

**Disadvantages**

- (1) Transpiration often results in water deficit which causes injury to the plants by desiccation.
- (2) Rapid transpiration causes mid-day leaf water deficit (temporary wilting). If such condition continues for some time, permanent water deficit (permanent wilting) may develop, which causes injury to plants.
- (3) Many xerophytes have to develop structural modifications to reduce transpiration. These modifications are extra burden on the plants.
- (4) Excessive rate of transpiration leads to stunted growth of plants.

(5) Since approximately 90 percent of absorbed water is lost through transpiration, the energy used in absorption and conduction of water goes waste.

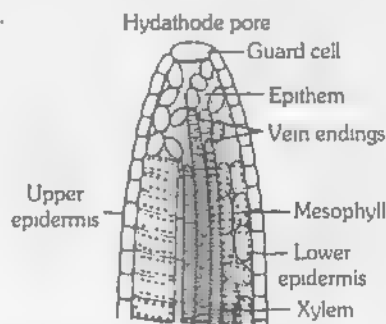
Curtis (1926) truly called 'transpiration as a necessary evil'

**Anti-transpirants :** The chemical substances which reduce transpiration (by increasing leaf resistance to water vapour diffusion) without affecting gaseous exchange, are called anti-transpirants'. Anti-transpirants are of two types metabolic inhibitors and film forming anti-transpirants.

**Metabolic inhibitors :** They reduce transpiration by causing partial closure of stomata without influencing other metabolite processes, the most important of these inhibitors are phenyl mercuric acetate (PMA), and abscisic acid (ABA).

**Film forming anti-transpirants :** They check transpiration by forming a thin transparent film on the transpiring surface. They are sufficiently permeable to carbon dioxide and oxygen to allow photosynthesis and respiration, but prevent movement of water vapour through them. The important chemicals of this group are silicon emulsion, colourless plastic resins and low viscosity waxes.

**Guttation :** The process of exudation of liquid drops from the edges of leaves (during night or early morning) is called guttation or the process of the escape of liquid from the tip of uninjured leaf is called guttation. It was first studied by Bergerstein in 1887. Usually it occurs through stomata like pores called hydathodes (Water Stomata). Exudation may sometime occur from stem through the scars of leaves and lenticles. Guttation usually occurs when the plant is put in more saturated atmosphere.



**Fig : 4.1-8 Vertical section of a leaf showing hydathode**

Hydathodes are generally present at the tip or margin of leaves. These pores are present over a mass of loosely arranged cells with large intercellular spaces called epithem. This mass of tissue lies above a vein ending. The xylem of a small vein usually terminates among the thin walled parenchymatous cells of epithem. Guttation is caused due to root pressure. It is found in 115 families and 333 genera of woody and herbaceous plants. e.g., Garden nasturtium (*Tropeolum*), Oat (*Avena*), *Colocasia* etc. growing in moist, warm soil and under humid conditions. When the absorption of water exceeds that of the transpiration, hydrostatic pressure is built up in xylem ducts. As a result, water is pushed in the xylem ducts and comes out through the hydathodes. The water of guttation contains several dissolved inorganic and organic substance.

## Translocation of organic solutes

"The movement of organic food or solute in soluble form, from one organ to another organ is called translocation of organic solutes"

The process of translocation requires expenditure of metabolic energy and the solute moves at the rate of 100 cm/hr.

### Directions of translocation

**Downward translocation :** It is of most important type, i.e., from leaves to stem and roots.

**Upward translocation :** From leaves to developing flowers, buds, fruits and also during germination of seeds and tubers, etc

**Radial translocation :** From pith to cortex and epidermis.

### Path of translocation

(1) **Downward translocation of organic solutes :** Phloem is the path for downward translocation of organic food. Following evidences are in support of it :

(i) **Elimination of other tissues :** Xylem is responsible for upward movement of water and minerals, so it cannot account for downward translocation of solute at the same time. Thus only phloem is left (where there is end to end arrangement of sieve tubes united by sieve pores). Which is responsible for translocation of solutes in downward direction.

(ii) **Chemical analysis of phloem sap and xylem sap :** Chemical analysis of sieve tube sap proves that concentrated solution of sucrose is translocated from the place of synthesis to other parts of the plant body. Glucose and fructose are sometimes found in traces only. The amount of sucrose is more in phloem sap during the day and less in night. In xylem the amount of sucrose is in traces and also there is no diurnal fluctuation.

(iii) **Blocking of phloem :** Blocking of sieve pores by 'callose' during winter blocks translocation of solutes.

(iv) **Ringing or Girdling experiment :** It was first performed by Hartig (1837). On removing the ring of bark (phloem + cambium) above the root at the base of stem, accumulation of food occurs in the form of swelling just above the ring, which suggests that in absence of phloem, downward translocation of food is stopped.

(v) **Structure of phloem :** The structure of phloem tissue is well modified for conduction of solutes. Phloem tissue of an angiosperm consists of sieve tubes, companion cells several kinds of parenchyma cells, fibres and scleroids. Of these sieve tubes are involved in sugar translocation.

(2) **Upward translocation of organic solutes :** According to Curtis upward conduction of foods also takes place through phloem.

### Mechanism of translocation

**Diffusion hypothesis :** Mason and Maskel (1928) working on cotton plant demonstrated that the translocation of foods occurs from the place of high concentration (place of manufacture or storage) to the place of lower concentration (place of consumption) but it is very slow process so Mason and Phillis (1936) modified this concept and proposed activated diffusion hypothesis. According to this concept the food particles are first energy activated then translocated. This hypothesis is not accepted due to lack of experimental evidence.

**Protoplasmic streaming hypothesis :** This concept was proposed by de Vries (1885). According to him the food is transported across by streaming current of protoplasm. The cell protoplasm shows a special locomotion movement called cyclosis. It is of two types, rotation and circulation. While rotation is circular movement of protoplasm, circulation is radial movement forming eddies around the vacuoles. The hypothesis involves two phenomenon, such as streaming of sieve protoplasm and diffusion of metabolites through sieve pores.

This hypothesis not only explains faster rate of translocation but also the bidirectional movement of metabolites across a single sieve element. This hypothesis was supported by Curtis (1950).

**Transcellular streaming :** Thaine (1964) suggested modification to cytoplasmic streaming theory. He defined transcellular streaming as "the movement of the particulate and fluid constituents of cytoplasm through linear files of longitudinally oriented plant cells." He further proposed that transcellular strands are proteinaceous and characteristic microtubules to afford rhythmic contraction. Thus, transcellular streaming is an attractive mechanism as it would explain the phenomenon of bidirectional translocation.

**Electro-osmotic hypothesis :** A mechanism involving electro-osmosis was proposed independently by Fensom (1957) and Spanner (1958). According to this hypothesis the solute moves in the positive direction of the electrical gradient along with  $K^+$  ions.

**Munch's mass flow or pressure flow hypothesis :** The mass flow or pressure flow mechanism was first proposed by Hartig (1860). It was later modified by Munch (1930). Crafts elaborated it further in 1938. Munch assumed that the protoplasm of sieve tube is connected through plasmodesmata and forms a continuous system, called as the symplast. The translocation of solutes occurs in a mass alongwith cell sap through the sieve tubes from a region of higher turgor pressure to low turgor pressure (i.e., along a turgor pressure gradient).

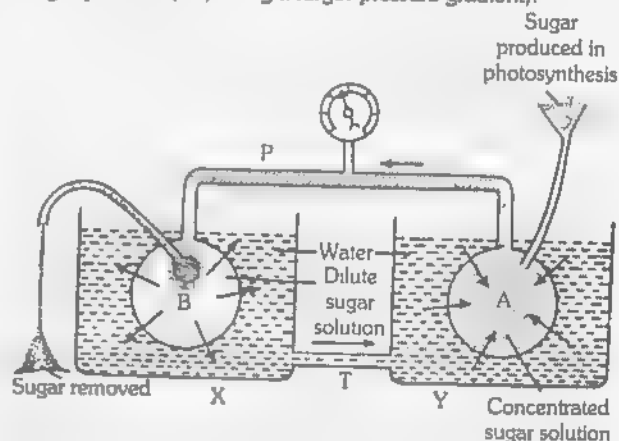


Fig : 4.1-9 A model demonstrating the Munch mass flow hypothesis

**Munch's hypothesis has been supported further by the following :**

When a woody or herbaceous plant is girdled, the sap containing high sugar content exudates from the cut end. Positive concentration gradient disappears when the plants are defoliated. Movement of viruses and growth hormones is fast in illuminated leaves as compared to shaded leaves.

**Objections :**

The hypothesis fails to explain bidirectional movement of metabolites which is common in plants. Osmotic pressure of mesophyll cells and that of root hair do not confirm the requirements. Munch's hypothesis gives a passive role to the sieve tube elements and the protoplasm.

**Factors affecting translocation**

**Temperature :** Optimum temperature for translocation ranges between 20-30°C. The rate of translocation increases with the increase of temperature upto an upper limit and then starts declining. At low temperature, the rate of translocation decreases.

**Light :** Hartt and his coworkers (1964) proposed that the movement of assimilates of a leaf can depend upon radiant energy. The increase in light intensity more food starts being translocated to roots than to shoots. At lower intensity the growth of root and shoot is inhibited thereby the rate of translocation also decreases.

**Hormones :** Cytokinins have a pronounced effect on the translocation of water soluble nitrogen compounds.

**Oxygen :** Oxygen is necessary during transfer of food from mesophyll cells into phloem which is called as phloem loading.

**Minerals :** Boron is highly essential for translocation of sugar. Phosphorus also helps in translocation of solutes.

**Water :** Translocation of photosynthates out of the leaves is highly sensitive to the amount of water in the plant cells.

**Metabolic inhibitors :** The metabolic inhibitors which inhibit the process of respiration (e.g., iodoacetate, HCN, carbon monoxide etc.) adversely affect the process of translocation because phloem loading and unloading require ATP.

## Tips & Tricks

- ✚ Stephen Hales is known as father of plant physiology. Coined the term root pressure.
- ✚ The osmotic pressure of a solution can be measured with the help of a apparatus called osmometer.
- ✚ Molar solution : 1gm mole of solute plus 1 litre / 1000cc of solution.
- ✚ Molal solution : 1gm mole of solute plus 1 litre / 1000cc of solvent.
- ✚ Cryoscopic osmometer measures the osmotic potential of solution by measuring its freezing point.
- ✚ Tensiometer is the instrument for measuring soil water potential.
- ✚ The amount of water left in the soil after the plant has permanently wilted is the wilted coefficient.
- ✚ Humus and clay are two colloidal complexes of soil.
- ✚ Cohesive force is called as tensile strength of water.
- ✚ Manometer (Gk. manos – thin, metron – measure). An instrument for measuring pressure of tension (such as root pressure) in gases and liquids.

✚ Cohesive strength of 47-207 atm. in xylem sap is sufficient to meet the stress of transpiration pull, so that water column does not break.

✚ Osmotic pressure is maximum in noon. At this time water contents in the cell are minimum.

✚ Osmotic pressure is highest in halophytes.

✚ In night, root pressure will be maximum because in night transpiration is zero

✚ Pressure bomb technique was used by Scholander et al.

✚ Psychrometer is used for measuring relative humidity as well as transpiration.

✚ Hydrometer is used for measuring the density or specific gravity of a liquid

✚ Barometer is used for measuring atmospheric pressure.

✚ Barograph represents the recording of barometer.

✚ Porometer is used for measuring the size of stomata.

✚ Atmometer is used for measuring pull caused by evaporation of water from a porous pot.

✚ Potometer is used for measuring the rate of transpiration.

✚ Potometer works on the principle of amount of water absorbed equals the amount transpired.

✚ Transpiration on hills : High due to lower atmospheric pressure but low due to lesser hours of light and lower temperature. Transpiration is therefore, near normal but the plants show xeromorphy due to lesser water availability.

✚ In Saxifraga, the rate of guttation is high during flowering.

✚ Maximum opening of stomata occurs at about 10:00 AM and 3:00 PM (At 12:00 noon, partial closure of stomata occurs).

✚ In  $C_3$  plant the rate of transpiration is high

✚ Cobalt chloride paper method was first used by Stahl (1894). It is used to compare rate of transpiration on two surfaces of leaf. Cobalt chloride is blue in anhydrous state. In contact with water vapour it turns pink.

✚ Bleeding is the exudation of sap (water along with dissolved organic and inorganic substances) from the injured parts of the plant e.g., exudation of latex from laticiferous ducts in Euphorbia and members of family moraceae (mulberry family) are the cases of bleeding.

✚ When transpiration is very low and absorption is high, the root pressure is maximum.

✚ In aquatic and submerged plants stomata are absent e.g., Vallisneria.

✚ Mittler (1958) develop a technique for the collection of phloem sap using an aphid stylet.

✚ The principle pathway by which water is translocated in angiosperm is xylem and vessels.

# Ordinary Thinking

## Objective Questions

### General

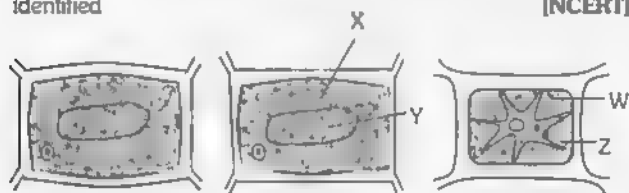
1. The sugarcane plant has [AIIMS 2004]
  - (a) Dumb-bell shaped guard cells
  - (b) Pentamerous flowers
  - (c) Reticulate venation
  - (d) Capsular fruits
2. Some leaves are removed from the stem cuttings planted for vegetative propagation. This is done [BHU 1994]
  - (a) To increase water uptake
  - (b) Because it helps in rooting of cuttings
  - (c) To reduce water loss
  - (d) Because the cuttings need less food
3. Exchange of substances between individual cells and their environments takes place by [BHU 2002]
  - (a) Osmosis
  - (b) Diffusion
  - (c) Active transport
  - (d) All of these
4. When a bark of tissue is cut from stem, of which the vascular tissue is removed
  - (a) Xylem
  - (b) Phloem
  - (c) Parenchyma
  - (d) None of these
5. Best soil for healthy and vigorous growth of a plant is [BVP 2004; CPMT 2010]
  - (a) Sandy soil
  - (b) Loam
  - (c) Clay
  - (d) None of these
6. Soil formed after leaching and rich in Al and Fe is [DPMT 2004]
  - (a) Alluvial
  - (b) Podzol
  - (c) Laterite
  - (d) None of these
7. Active transport of ions by the cell requires [MP PMT 2002]
  - (a) High temperature
  - (b) ATP
  - (c) Alkaline pH
  - (d) Salts
8. Good soil is [CPMT 2004]
  - (a) Which holds whole of the water that enters into it
  - (b) Which allows percolating the water slowly from it
  - (c) Which allows water to pass very quickly from it
  - (d) Which allows limited amount of water to retain into it
9. Lenticels and hydathodes are small pores with following common attributes [BHU 1994]
  - (a) Their opening and closing is not regulated
  - (b) They allow exchange of gases
  - (c) They always remain closed
  - (d) They are found on the same organ of plants
10. Which of the events is more rapid
  - (a) Suction of water and minerals due to transpiration pull
  - (b) Cyclosis in cell cytoplasm
  - (c) Sugar transport in phloem
  - (d) Distribution of hormones from one part to other
11. Attractive forces of cell walls for water molecules is termed as [NCERT; Kerala PMT 2010]
  - (a) Adhesion
  - (b) Cohesion
  - (c) Osmosis
  - (d) Plasmolysis
12. In trees, death of protoplasts is essential for a vital function such as [BHU 1994]
  - (a) Stomatal movements
  - (b) Both water and food transport
  - (c) Water transport
  - (d) Food transport
13. Which of the following is not a function of water in cell [RPMT 2002]
  - (a) It provides energy for chemical reaction
  - (b) It acts as a solvent
  - (c) It provides a medium for chemical reaction
  - (d) It releases hydrogen ions on ionisation
14. Active absorption is affected by [RPMT 1999]
  - (a) Osmotic concentration
  - (b) Associate tissue structures
  - (c) Transpiration
  - (d) Sucking capacity of root hair
15. Which one of the following doesn't help in molecule transport [BHU 2003]
  - (a) Diffusion
  - (b) Osmosis
  - (c) Surface tension
  - (d) Active transport
16. Root cap has no function in water absorption, because
  - (a) Its vascular system is not directly connected
  - (b) Its cells are loosely placed
  - (c) It has cells without chloroplast
  - (d) It has no root hair
17. Water infiltration will be slowest in [AIEEE Pharmacy 2004]
  - (a) Black cotton soil
  - (b) Sandy soil
  - (c) Red soil
  - (d) Loamy soil
18. Meaningful girdling (Ringing) experiments cannot be done on sugarcane because [CBSE PMT 1994]
  - (a) Phloem is present inside the xylem
  - (b) It can not tolerate the injury
  - (c) Vascular bundles are scattered
  - (d) Plants are very delicate
19. The amount of water held by the soil after drainage is known as [BHU 1999]
  - (a) Mineral water
  - (b) Soil water
  - (c) Field capacity
  - (d) Gravitational capacity

### Membranes, Osmosis, Diffusion, Imbibition, Plasmolysis and Wilting

1. Osmosis is the diffusion of [NCERT; Odisha JEE 2008]
  - (a) Solute
  - (b) Free energy
  - (c) Water
  - (d) Solute and solvent



2. The relationship  $\mu = nRT$  is not obeyed by  
[Odisha JEE 2012]  
(a) Concentrated solution (b) Dilute solution  
(c) Extremely dilute solution (d) All of these
3. That the cell membrane is selectively permeable can be best deduced by  
(a) The entry of water from root hair  
(b) The entry of mineral salts from the root hair  
(c) Both together  
(d) The rise of sap in plants
4. The cell wall is permeable and not a semipermeable structure can be best deduced from the passage of water and mineral salts from  
(a) Soil into periplasmic space of root hairs  
(b) Root hairs to cortical cells  
(c) Cortical cells to pericycle  
(d) Pericycle to trachea
5. What happens when formalin preserved *Spirogyra* filament is placed in a hypertonic sugar solution  
(a) It gains turgidity (b) It loses turgidity  
(c) It becomes plasmolysed (d) Nothing happens
6. Selective permeability identifies the process of transmission through semipermeable membrane is called [AFMC 2003]  
Or  
The movement of water from higher water potential to lower water potential through a semi-permeable membrane is called [J & K CET 2010; WB JEE 2016]  
Or  
Living cells placed in isotonic solution (0.9% saline) retain their size and shape. This is based on the concept of [WB JEE 2012]  
(a) Diffusion (b) Osmosis  
(c) Plasmolysis (d) Imbibition
7. The process of osmosis involves  
(a) Movement of solute through semipermeable membrane  
(b) Movement of solvent through a semipermeable membrane  
(c) Movement of solution through a semipermeable membrane  
(d) None of the above
8. The given figure shows plasmolysis in cell. A is normal turgid cell, B shows incipient plasmolysis and C is plasmolysed cell. Select the right option in which W, X, Y and Z are correctly identified [NCERT]



- (a) Shrunken protoplast, Protoplast, Vacuole, Hypotonic solution  
(b) Shrunken protoplast, Flaccid protoplast, Vacuole, External solution  
(c) Turgid protoplast, Protoplast, Vacuole, External solution  
(d) Shrunken protoplast, Protoplast, Vacuole, External solution

9. Assume that an actively respiring cell has  $3x$  number of  $K^+$  in its cytoplasm and  $2x$  number of  $K^+$  outside. After sometime,  $x$  number of  $K^+$  entered into the cell. What is the process by which  $K^+$  transport has taken place [EAMCET 2009]  
(a) Primary active transport  
(b) Secondary active transport  
(c) Diffusion  
(d) Passive transport
10. A RBC and a plant cell (with thick cell wall) are placed in distilled water. The solute concentration is the same in both the cells. What changes would be observed in them [KCET 2009]  
(a) Both plant cell and RBC would not undergo any change  
(b) The RBC would increase in size and burst while the plant cell would remain about the same size  
(c) The plant cell would increase in size and burst while the RBC would remain about the same size  
(d) Both plant cell and RBC would decrease in size and collapse
11. In the process of osmosis [AFMC 1995]  
(a) Both protoplasm and cell wall act as a single layer  
(b) Only protoplast acts as a single layer  
(c) Only cell membrane acts as a single layer  
(d) None of the above
12. A professor kept some moist seeds in an airtight jar and started lecturing. At the end of the experiment an explosion occurred in the jar. What did the professor want to explain [CBSE PMT 1990]  
(a) Osmosis (b) Diffusion  
(c) Anaerobic respiration (d) Imbibition
13. Plant cell plasmolysed in a solution which is [MP PMT 1998, 2006; Odisha JEE 2008]  
Or  
If a cell is reduced in size on placing in a solution of sugar, the solution is [RPMT 2002; AFMC 2009]  
(a) Hypotonic (b) Hypertonic  
(c) Isotonic (d) Concentration no means
14. Osmosis is defined as the process in which [MP PMT 1998]  
(a) Water diffuses from lower concentration to higher concentration  
(b) Solutes diffuse from lower concentration to higher concentration  
(c) Active transport of ions takes place  
(d) Passive transport of ions takes place
15. Graham's law is correlated with [WB JEE 2009]  
(a) Diffusion (b) Osmoregulation  
(c) Osmosis (d) Adsorption
16. The first process by which water enters into the seed coat when a seed is placed in suitable environment for germination is [Bihar MDAT 1995; KCET 2007; Kerala PMT 2011]  
Or  
In seed germination, the first phenomenon that takes place is [Bihar MDAT 1995]  
(a) Osmosis (b) Active transport  
(c) Absorption (d) Imbibition



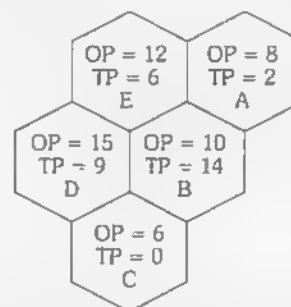
17. Which of the following experiment is called physiological demonstration of osmosis [KCET 2007]
  - (a) Thistle funnel – whose mouth is tied with egg membrane
  - (b) Thistle funnel – whose mouth is tied with parchment paper
  - (c) Potometer
  - (d) Bell jar experiment
18. An example of selectively permeable membrane is
  - (a) Plasmalemma
  - (b) Cell wall
  - (c) Mitochondrial membrane
  - (d) Chloroplast membrane
19. Plasma membrane controls
  - (a) Passage of water
  - (b) Passage of water and some solutes in and out of the cell
  - (c) Passage of water and solutes into the cell
  - (d) Movements of the cell contents out of the cell
20. Which plant is used for demonstrating plasmolysis in the laboratory
  - (a) *Tropeolum*
  - (b) *Impatiense balsamia*
  - (c) *Tradescantia*
  - (d) All the above
21. Force developed in cortex of root which pushes water into xylem of root from soil [Odisha JEE 2005]
  - (a) Diffusion
  - (b) Osmotic pressure
  - (c) Turgor pressure
  - (d) Root pressure
22. Plant cells submerged in distilled water will become [MP PMT 1998]
  - (a) Turgid
  - (b) Flaccid
  - (c) Plasmolysed
  - (d) Impermeable
23. Process of osmosis shall cease when
  - (a) Solutions become isotonic or DPD becomes equal
  - (b) Water concentration becomes equal
  - (c) There is no light
  - (d) The level of water falls
24. Which of the following has more imbibition power
  - (a) Cellulose
  - (b) Hemicellulose
  - (c) Fat
  - (d) Protein
25. Wilting occurs when [AFMC 2004, 08]
  - (a) Rate of transpiration is higher than absorption
  - (b) Rate of absorption is higher than transpiration
  - (c) Excess root pressure
  - (d) High relative humidity in air
26. When plant cells are kept in a concentrated salt solution, they are [MP PMT 1994; BVP 2004]
  - (a) Deplasmolysed
  - (b) Plasmolysed
  - (c) Remains as such
  - (d) Becomes turgid
27. The initial stage of water absorption by root cells is by  
Or  
Dry seeds when placed in water swells due to [NCERT; CPMT 1994]
  - (a) Adsorption
  - (b) Absorption
  - (c) Osmosis
  - (d) Imbibition
28. The process by which large molecules move out of the cell is called
  - (a) Plasmolysis
  - (b) Deplasmolysis
  - (c) Phagocytosis
  - (d) Reverse phagocytosis
29. In the process of plasmolysis [CPMT 1995]
  - (a) Endosmosis occurs
  - (b) Exosmosis occurs
  - (c) Imbibition occurs
  - (d) Diffusion occurs
30. In the process of osmosis, volume of solvent [AFMC 1996]
  - (a) Increases
  - (b) Decreases
  - (c) Remains same
  - (d) Volume is not related in osmosis
  - (e) Endosmosis
31. The membrane which allows passage of certain substances more readily than others is termed as [BVP 2003]
  - (a) Impermeable
  - (b) Semisolid
  - (c) Permeable
  - (d) Selectively permeable
32. What shall be the sequence of events during wilting of a plant [Kerala CET 2002]
  - (a) Exosmosis, deplasmolysis, wilting
  - (b) Endosmosis, plasmolysis, wilting
  - (c) Exosmosis, plasmolysis, wilting
  - (d) Endosmosis, deplasmolysis, wilting
33. A plasmolysed cell can be deplasmolysed by placing it in [BVP 2002]
  - (a) Isotonic solution
  - (b) Hypertonic solution
  - (c) Saturated solution
  - (d) Pure water or hypotonic solution
34. What would happen if a thin slice of sugar beet is kept in NaCl [CPMT 2002]
  - (a) It should lose water from the cell
  - (b) It should become turgid
  - (c) It should neither absorbed water nor lose it
  - (d) It should absorb water from the soil solution
35. When a potato piece is kept in a highly concentrated salt solution, then [CBSE PMT 2002]
  - (a) Potato is plasmolysed
  - (b) Potato is deplasmolysed
  - (c) Potato cells get bursted
  - (d) There is no effect due to isotonic solution
36. Osmosis is helpful to plant because
  - (a) Growth of the young cells is brought about by osmotic pressure and turgor pressure of these cells
  - (b) Certain turgor moments in plants are determined by osmosis
  - (c) Both (a) and (b)
  - (d) None of these
37. In rainy season, the doors get wet due to [AIIMS 2001; GUJCET 2015]
  - (a) Imbibition
  - (b) Absorption
  - (c) Diffusion
  - (d) Endosmosis
38. Due to plasmolysis, the plant cell [Kerala CET 1999; GUJCET 2014]
  - (a) Bursts
  - (b) Swells up
  - (c) Becomes turgid
  - (d) Becomes flaccid

39. The plant undergoes wilting when [CPMT 1993, 94, 2002; AFMC 2005; RPMT 2005; BHU 2006; WB JEE 2009]
- Xylem is blocked
  - Cambium is blocked
  - Phloem is blocked
  - Some roots are reduced in number
40. In some plants, the leaves droop down during day while become normal during night
- Due to temporary wilting
  - Permanent wilting
  - Both (a) and (b)
  - None of the above
41. Wilting of a plant results from excessive [CPMT 1994; AFMC 2001]
- Respiration
  - Photosynthesis
  - Absorption
  - Transpiration
42. The plants face wilting due to use of excessive fertilizers because of [CPMT 1998]
- Exosmosis
  - Endosmosis
  - Imbibition
  - None of these
43. How water rises from the rhizoids of *Riccia* to its assimilatory filaments? It is through
- Osmosis
  - Root pressure
  - Capillary
  - Transpiration pull
44. Which of the following seeds will show more imbibitional pressure
- Til seeds
  - Gram seeds
  - Wheat seeds
  - Rice seeds
45. Movement of molecules of gases, liquids and solids from a region of higher concentration to a region of lower concentration is termed as [KCET 1994; RPMT 1995]
- Or
- Movement of particles of matter in the cell due to its own kinetic energy is called
- Diffusion
  - Evaporation
  - Transpiration
  - Osmosis
46. During osmosis, water moves through a membrane [MP PMT 1993; RPMT 1999]
- | FROM                                   | TO                                  |
|--|-------------------------------------|
| (a) Low water potential                | High water potential                |
| (b) High solute concentration          | Low solute concentration            |
| (c) High osmotic potential             | Low osmotic potential               |
| (d) A hypotonic solution (less solute) | A hypertonic solution (more solute) |
47. Incipient plasmolysis is [WB JEE 2016]
- Last stage of plasmolysis
  - Mid stage of plasmolysis
  - Zero hour for inception of plasmolysis
  - Initial stage of plasmolysis

### O.P., T.P., I.P., D.P.D and Water potential

1. The osmotic parameter determining flow of water from one cell to another is
- Or
- The actual pressure with which water enters into cell is called [Pb. PMT 1999, 2004]
- Osmotic pressure
  - Turgor pressure
  - Diffusion pressure deficit
  - Hydrostatic pressure

2. Addition of solute in the cell develops [AFMC 2008]
- Or
- DPD of a cells mainly depends upon [BHU 2012]
- TP
  - OP
  - DP
  - WP
3. 0.1M solution of a solute has a water potential of [MP PMT 1995; BVP 2002]
- 2.3 bars
  - 0 bar
  - 22.4 bars
  - + 2.3 bars
4. Root pressure develops due to [AIPMT 2015]
- Low osmotic potential in soil
  - Passive absorption
  - Increase in transpiration
  - Active absorption
5. Which of the following statements are true / false
- The positive hydrostatic pressure is called turgor pressure
  - Wall pressure exerts to prevent the increase of protoplasm size
  - Diffusion is more rapid in liquids than in gases
  - Diffusion of water through a semi-permeable membrane is called imbibition
  - Osmosis is movement of substances which takes place along a diffusion gradient
- [Kerala PMT 2006]
- A and B are true & C, D and E are false
  - A and C are true & B, D and E are false
  - A and D are true & B, C and E are false
  - A and E are true & B, C and D are false
  - C, D and E are true & A and B are false
6. See the following diagram, when the TP of the cell B increases to 18. What changes would occur with regard to water movement [NCERT]



- No movement of water will occur
  - B actively absorb water from neighbor cell
  - Water diffuses into B from outer cell
  - Cells A, C, D and E absorb water from B
7. Observe the following experiment



After a few days, which of the following changes will have occurred [NCERT]

- A drop in level X and a rise in level Y
- A rise in level X and a rise in level Y
- A drop in level X and a drop in level Y
- A rise in level X and a drop in level Y

8. Cell A has osmotic potential of  $-18$  bars and pressure potential of  $8$  bars, whereas, cell B has osmotic potential of  $-14$  bars and pressure potential  $2$  bars. The direction of flow of water will be [AIIMS 2009]

(a) From cell B to cell A (b) From cell A to cell B  
(c) No flow of water (d) In both the directions

9. In hypertonic solution a cell water potential

(a) Decreases  
(b) Increases  
(c) First increases then decreases  
(d) No change

10. In a fully turgid cells, the values of DPD, OP and TP will show the tendency

Or

The cell is fully turgid when

[J & K CET 2002; WB JEE 2010; Odisha JEE 2010]

(a) DPD =  $10$  atm, OP =  $15$  atm, TP =  $5$  atm  
(b) DPD =  $5$  atm, OP =  $12$  atm, TP =  $7$  atm  
(c) DPD =  $2$  atm, OP =  $7$  atm, TP =  $5$  atm  
(d) DPD =  $0$  atm, OP =  $15$  atm, TP =  $15$  atm

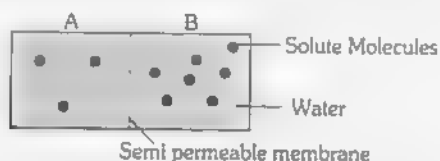
11. The osmotic potential and pressure potential of three cells (A, B, C) located in different parts of an actively transpiring plant are given below

Cell	Osmotic Potential (Mpa)	Pressure Potential (Mpa)
A.	$-0.87$	$0.44$
B.	$-0.92$	$0.34$
C.	$-0.68$	$0.27$

Identify these three cells as root hair, root cortical and leaf mesophyll cells respectively [EAMCET 2009]

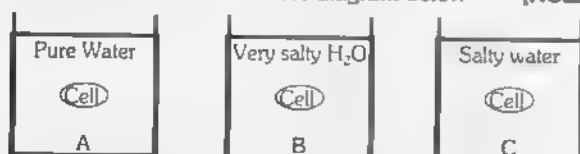
(a) A, B, C (b) A, C, B  
(c) C, A, B (d) B, C, A

12. See the following figure and point out the statement which is not correct [NCERT]



(a) The direction and the rate of osmosis depend upon both the pressure gradient and conc. gradient  
(b) Presence of a SPM is a prerequisite for this process to occur  
(c) Movement of solute will take place from chamber A to B  
(d) Movement of solvent molecules will take place from chamber A to B

13. Select the correct statement for diagram below [NCERT]



(a) Cell "A" will gain  $H_2O$ , Cell "B" will lose  $H_2O$ , Cell "C" neither gain nor loses  $H_2O$   
(b) Cell "A" will gain  $H_2O$ , Cell "B" neither gain nor loses  $H_2O$ , Cell "C" will lose  $H_2O$   
(c) Cell "A" neither gain nor loses  $H_2O$ , Cell "B" will gain  $H_2O$ , Cell "C" will lose  $H_2O$   
(d) Cell "A" will lose  $H_2O$ , Cell "B" will gain  $H_2O$ , Cell "C" neither gain nor loses  $H_2O$

14. Two cells A and B are contiguous. Cell A has osmotic pressure  $10$  atm, turgor pressure  $7$  atm and diffusion pressure deficit  $3$  atm. Cell B has osmotic pressure  $8$  atm, turgor pressure  $3$  atm and diffusion pressure deficit  $5$  atm. The result will be [CBSE PMT 2007]

(a) Movement of water from cell B to A  
(b) No movement of water  
(c) Equilibrium between the two  
(d) Movement of water from cell A to B

15. If water enters in a cell, the pressure exerted by its swollen protoplast is [AFMC 2004]

Or

Turgidity of the cells is maintained by

(a) Turgor pressure (b) DPD  
(c) Osmotic pressure (d) Imbibition

16. Addition of a solute to pure water causes [MP PMT 2001]

(a) Negative water potential  
(b) More negative water potential  
(c) Positive water potential  
(d) More positive water potential

17. The ratio of osmotic pressure exerted by  $1$  M sucrose and  $1$  M NaCl solution will be [AIIMS 2010]

(a)  $1$  (b)  $2$   
(c)  $0.1$  (d)  $0.5$

18. When osmotic potential is either zero or negative and pressure potential is positive, then the water potential will be

(a) Negative  
(b) Positive  
(c) Sometimes negative and sometimes positive  
(d) None of the above

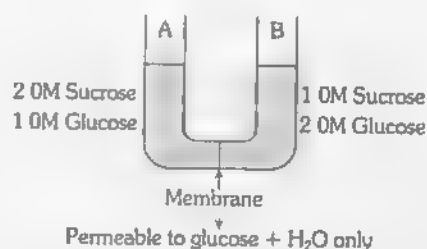
19. Which one of the following statements is wrong [Kerala PMT 2007]

(a) Water potential is the chemical potential of the water  
(b) Solute potential is always negative  
(c) Pressure potential is zero in a flaccid cell  
(d) Water potential equals solute potential in a fully turgid cell  
(e) Pressure potential is negative in a plasmolyzed cell

20. What will be the effect of accumulation of  $K^+$  ions in guard cells [GUJCET 2007]

(a) Water potential increases (b) Water potential decreases  
(c) Loss of turgidity (d) Exosmosis

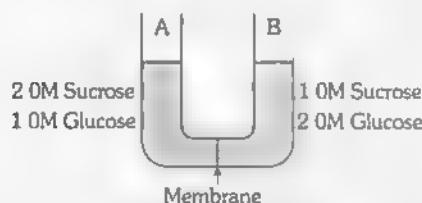
21. Observe the following figure



After the system reaches equilibrium, Which of the following changes will have occurred [NCERT]

(a) First the level of water is high in tube A and then water level is decreased  
(b) No change is observed  
(c) The water level is higher in side B than in side A  
(d) The water level is higher in side A than in side B

22. Under given suitable conditions, the DPD will be more than OP [BHU 1994]  
 (a) When OP is equal to TP  
 (b) When OP is less than TP  
 (c) When OP is greater than TP  
 (d) When TP is negative
23. Water is necessary for... [MP PMT 2005]  
 (a) Content of protoplasm (b) Solvent  
 (c) Reagent (d) All above
24. See the following diagram



Initially solution in side A, with respect to side B, is [NCERT]

- (a) Lower (b) Isotonic  
 (c) Hypertonic (d) Hypotonic
25. Water potential can be obtained by  
 (a)  $OP + TP$  (b)  $OP = WP$   
 (c)  $P + \pi$  (d)  $OP - DPD$
26. Solute potential of 0.1 solution is always [DUMET 2010]  
 (a)  $= 0$  (b)  $> 0$   
 (c)  $< 0$  (d) Between 0-1
27. Osmotic pressure of a solution is [BVP 2004]  
 (a) Greater than pure solvent  
 (b) Less than pure solvent  
 (c) Equal to pure solvent  
 (d) Less than or greater than pure solvent
28. Identify the correct relationship with reference to water potential of a plant cell. [KCET 2006]  
 (a)  $\psi_w = \psi_m + \psi_s + \psi_p$  (b)  $\psi_w = \psi_m + (\psi_s - \psi_p)$   
 (c)  $\psi_w = \psi_m - (\psi_s + \psi_p)$  (d)  $\psi_w = \psi_m - \psi_s - \psi_p$
29. Water potential  $\Psi$  measured in bar or in  
 (a)  $lb/in^2$  (b)  $mm$  of  $Hg$   
 (c)  $atm$  (d) All the above
30. Glucose is not stored in plant due to [CPMT 2010]  
 (a) Decrease in osmotic pressure  
 (b) Increase in osmotic pressure  
 (c) Increase in turgor pressure  
 (d) Decrease in turgor pressure
31. When osmotic pressure becomes equal to the wall pressure, then [CPMT 1995]  
 (a) The flow of water will be inside the cell  
 (b) The flow of water will be outside the cell  
 (c) Both flow will occur inside as well as outside  
 (d) There will be no flow
32. What will be the direction of movement of water, when a solution A having water potential of  $-9$  bars and another solution B of  $-4$  bars is separated by a semipermeable membrane [AFMC 2003; KCET 2010]  
 (a) B to A (b) A to B  
 (c) Both directions (d) None of these

33. Turgor pressure becomes equal to the wall pressure when [Pb. PMT 1999]  
 (a) Water leaves the cell  
 (b) No exchange of water takes place  
 (c) Water enters the cell  
 (d) Solute goes from the cell into water
34. When a plasmolysed cell is placed in a hypotonic solution then water will move inside the cell. Which force causes this [RPMT 2002]  
 (a) DPD (b) OP  
 (c) WP (d) None of these
35. When a cell is fully turgid, which of the following will be zero [CBSE PMT 1997]

Or

The potential energy of water is referred to as

[J & K CET 2005]

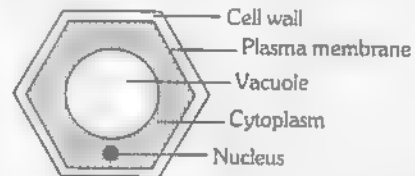
- (a) Wall pressure (b) Osmotic pressure  
 (c) Turgor pressure (d) Water potential
36. When water moves through a semipermeable membrane, which of the following is created [CPMT 1999; BHU 2000; CBSE PMT 2001]  
 (a) OP (b) SP  
 (c) TP (d) WP
37. Which statement is correct [DPMT 2004]  
 (a) Osmotic pressure of solution is greater than pure solvent  
 (b) Osmotic pressure of solution is lower than the pure water  
 (c) Osmotic pressure of solution is equal  
 (d) None of these
38. Which of the following equations is correct in respect of osmotic phenomenon [WB JEE 2016]  
 (a)  $DPD = OP - TP$  (b)  $DPD = OP + TP$   
 (c)  $DPD = OP \times TP$  (d)  $DPD = OP + TP$

### Absorption of water and Ascent of sap

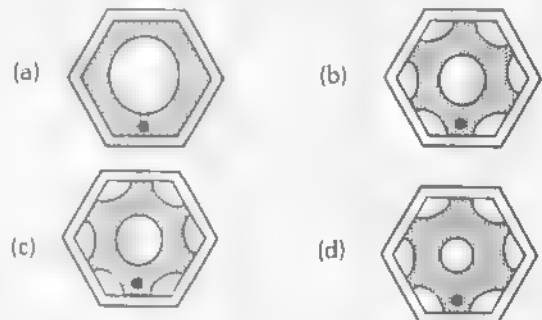
1. Transpiration and root pressure cause water to rise in plants by [AIPMT (Cancelled) 2015]  
 (a) Pulling and pushing it, respectively  
 (b) Pushing it upward  
 (c) Pushing and pulling it, respectively  
 (d) Pulling it upward
2. Most widely accepted explanation for the ascent of sap in tree is [RPMT 1995; Pb. PMT 1999, 2000; BHU 2001; CBSE PMT 2001; J & K CET 2002; Kerala PMT 2009]  
 (a) Capillarity  
 (b) Roll of atmospheric pressure  
 (c) Pulsating action of living cells  
 (d) Transpiration cohesion theory of Dixon

3. A column of water within xylem vessels of tall trees does not break under its weight because of [AIPMT 2015]
  - (a) Tensile strength of water
  - (b) Lignification of xylem vessels
  - (c) Positive root pressure
  - (d) Dissolved sugars in water
4. Which of the following is not true for active transport [Odisha JEE 2012]
  - (a) It is a chemical process
  - (b) Energy is required for this process which is obtained in the form of ATP
  - (c) It takes place through special organic molecules called carrier molecules
  - (d) This process is not modified by enzymes
5. Upward movement of water in plants is called [BHU 2012]
  - (a) Sucking
  - (b) Ascent of sap
  - (c) Translocation
  - (d) None of these
6. Water will be absorbed by root hairs when
  - (a) Concentration of salt in the soil is high
  - (b) Concentration of solutes in the cell sap is high
  - (c) Plant is rapidly respiring
  - (d) They are separated from soil by a permeable membrane
7. The factor or process which best explains the rise of water from roots (100 mts) to the top of tall tree is [UGET Manipal 1995, 96, 2005; KCET 2011; Odisha JEE 2011]
  - (a) Break down of ATP
  - (b) Root pressure
  - (c) Capillary rise of water in xylem
  - (d) Cohesion of water and transpiration pull
8. The path of water from soil upto secondary xylem is [Kerala PMT 2008; KCET 2012]
  - (a) Soil → Root hair cell wall → Cortex → Endodermis → Pericycle → Protoxylem → Metaxylem
  - (b) Metaxylem → Protoxylem → Cortex → Soil → Root hair
  - (c) Cortex → Root hair → Endodermis → Pericycle → Protoxylem → Metaxylem
  - (d) Pericycle → Soil → Root hair → Cortex → Endodermis → Protoxylem → Metaxylem
9. Physical force theory explains
  - (a) Non-living cells are not essential for ascent of sap
  - (b) Living cells are not essential for ascent of sap
  - (c) Ascent of sap may occur in both living and non-living cells
  - (d) Both (b) and (c)
10. The rupture and fractionation do not usually occur in the water column in vessel/tracheids during the ascent of sap because of [CBSE PMT 2008]
  - (a) Weak gravitational pull
  - (b) Transpiration pull
  - (c) Lignified thick walls
  - (d) Cohesion and adhesion
11. Which of the following would be in insignificant amount in xylem sap [KCET 2009]
  - (a) Sugar
  - (b) Nitrates
  - (c) Phosphates
  - (d) Water

12. Bordered pits relating with water uptake located in
  - (a) Cortex
  - (b) Endodermis
  - (c) Vessel elements (Xylem duct)
  - (d) Tracheary elements
13. Most of the water flow in the root takes place via the apoplast because [AMU (Med.) 2009]
  - (a) Cortical cells are loosely arranged
  - (b) Cortical cells are living cells
  - (c) Cortical cells are thin walled cells
  - (d) All of the above
14. The given diagram shows the appearance of plant cell immersed in a solution which is isotonic to the cell's sap



Which of the following diagrams shown below most accurately represents the appearance of this cell after immersion in a hypertonic solution [NCERT]

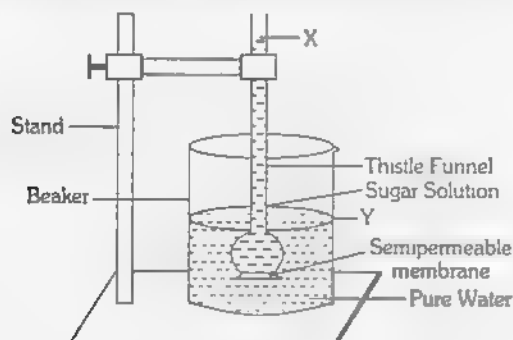


15. Which of the following helps in the absorption of water and mineral salts [CPMT 1994; AIIMS 1999]
  - (a) Mycorrhiza
  - (b) Anabaena
  - (c) Nostoc
  - (d) None of these
16. The given diagram indicates routes of transport of water and minerals from the soil through the root. Identify letters A, B, C and D [NCERT]



- (a) A - Apoplastic, B - Symplastic, C - Cellulosic strip, D - Xylem vessels
  - (b) A - Symplastic, B - Apoplastic, C - Cellulosic strip, D - phloem vessels
  - (c) A - Apoplastic, B - Symplastic, C - Casparian strip, D - Xylem vessels
  - (d) A - Symplastic, B - Apoplastic, C - Casparian strip, D - Xylem vessels
17. The movement of water from one cell of the cortex to the adjacent one in roots is due to [CBSE PMT 1995]
  - (a) Accumulation of inorganic salts in the cells
  - (b) Accumulation of organic compounds in the cells
  - (c) Chemical potential gradient
  - (d) Water potential gradient

III. Examine the experiment shown in the given figure



After a few days, which of the following changes will have occurred [NCERT]

- (a) A drop in level X and a rise in level Y
- (b) A rise in level X and a rise in level Y
- (c) A drop in level X and a drop in level Y
- (d) A rise in level X and a drop in level Y

19. Passage cells are thin walled cells found in [CBSE PMT 2007]

- (a) Endodermis of roots facilitating rapid transport of water from cortex to pericycle
- (b) Phloem elements that serve as entry points for substances for transport to other plant parts
- (c) Testa of seeds to enable emergence of growing embryonic axis during seed germination
- (d) Central region of style through which the pollen tube grows towards the ovary

20. Movement of  $H_2O$  through cell wall is called [DPMT 2007]

- (a) Apoplast (b) Symplast
- (c) Tonoplast (d) None of these

21. If two solutions have the same osmolarity, they are said to be [J & K CET 2005]

- (a) Hypertonic (b) Hypotonic
- (c) Isotonic (d) None of these

22. Which of the following statements is/are true

- A. The apoplastic movement of water occurs exclusively through the cell wall without crossing any membranes
- B. Solutes present in a cell (or in any solution) increase the free energy of water or water potential
- C. The symplastic movement occurs from cell to cell through the plasmodesmata
- D. Membrane permeability depends on the membrane composition, as well as the chemical nature of the solute [Kerala PMT 2007]

- (a) A and B only (b) B and D only
- (c) A, C and D only (d) A, B and D only
- (e) C only

23. Which of the following statements is incorrect

- (a) Water and salts are taken simultaneously by root hairs
- (b) Plants absorb one thing at a time either water or inorganic salt
- (c) Plants absorb excess quantity of water
- (d) All of the above

24. Apoplastic movement of water in plants occurs through

[DUMET 2010]

- (a) Casparian strips (b) Plasma membrane
- (c) Intracellular spaces (d) Plasmodesmata

25. When the concentration of the soil solutes is low, the absorption of water [KCET 2007]

- (a) Remains normal (b) Is stopped
- (c) Is increased (d) Is decreased

26. Simultaneous movement of two molecules across a membrane in the same direction is known as [NCERT; DUMET 2010]

- (a) Antiport (b) Symport
- (c) Uniport (d) Biport

27. Most accepted theory for ascent of sap is [BHU 2006]

Or

Sap ascends in woody stems because of root pressure and

- (a) Capillarity theory (b) Root pressure theory
- (c) Pulsation theory (d) Transpiration pull

28. Root system in a plant is well developed [CBSE PMT 1990]

- (a) Due to deficiency of auxin
- (b) Due to deficiency of cytokinins
- (c) Due to deficiency of minerals
- (d) For increased absorption of water

29. During absorption of water by roots, the water potential of cell sap is lower than that of [BHU 1994]

- (a) Pure water and soil solution
- (b) Neither pure water nor soil solution
- (c) Pure water but higher than that of soil solution
- (d) Soil solution but higher than that of pure water

30. Storage capacity of the soil is the extent to which it can hold [RPMT 1995; Pune CET 1998; WB JEE 2016]

Or

In soil, water available for plants is [CBSE PMT 1999; KCET 1999; BVP 2001; DUMET 2009]

- (a) Gravitational water (b) Capillary water
- (c) Hygroscopic water (d) All of the above

31. Active transport is characterized by

[RPMT 1997; AMU (Med.) 2010]

- (a) Requires special membrane proteins
- (b) Highly selective
- (c) Requires ATP energy
- (d) All of the above

32. The transport of water and salts takes place through

[CPMT 1996; MP PMT 1999, 2006]

- (a) Phloem (b) Xylem
- (c) Sieve tubes (d) Sclerenchyma

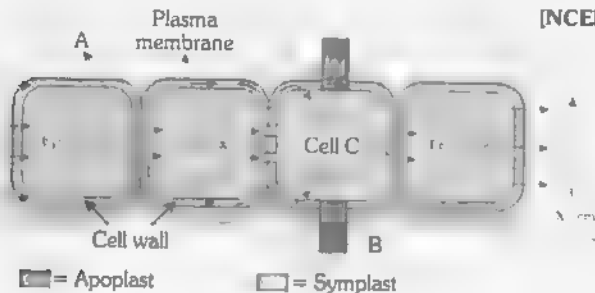
33. The direction of water in the leaflets of *Cycas* from midrib is

[CPMT 1998]

- (a) Lateral (b) Downward
- (c) Upward (d) Downward and upward

34. In plants, water supply is due to [BHU 2006]  
 (a) Osmosis (b) Imbibition  
 (c) Guttation (d) Adhesion force

35. The following diagram represent the pathway of water movement in the root. Identify A, B and C respectively [NCERT]



- (a) Plasmodesmata, Casparian strip, Endodermis  
 (b) Tight junction, Casparian strip, Endodermis  
 (c) Gap junction, Casparian strip, Endodermis  
 (d) Desmosome, Casparian strip, Endodermis
36. The principle pathways by which water is translocated in angiosperms is [CBSE PMT 1990; BHU 2012]  
 (a) Xylem and phloem together  
 (b) Sieve tubes and members of phloem  
 (c) Sieve cells of phloem  
 (d) Xylem vessel system
37. Passive absorption of water by the root system of the result of [KCET 2006, 10]  
 (a) Forces created in the cells of the root  
 (b) Increased respiratory activity in root cells  
 (c) Tension on the cell sap due to transpiration  
 (d) Osmotic force in the shoot system
38. Root hair absorb water from the soil on account of [RPMT 2005]  
 (a) Turgor pressure (b) Osmotic pressure  
 (c) Suction pressure (d) Root pressure
39. The ability to rise in thin tubes and the Ability to resist a pulling force are respectively referred to as [Kerala PMT 2012]  
 (a) Tensile strength and capillarity  
 (b) Adhesion and capillarity  
 (c) Cohesion and adhesion  
 (d) Cohesion and capillarity  
 (e) Capillarity and tensile strength
40. Ascent of sap is due to which force [RPMT 1999]  
 Or  
 The most important force which pulls water up in tall trees is  
 (a) Imbibition (b) Cellular force  
 (c) Cohesive force (d) Atmospheric pressure

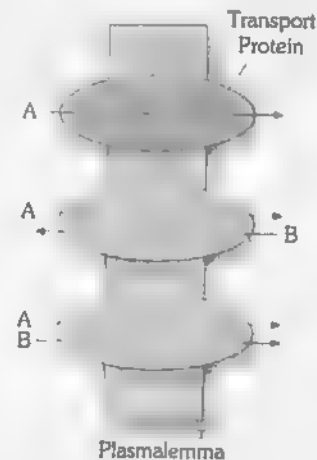
41. When water enters in roots due to diffusion, it is termed as [AFMC 1999; BHU 2001]  
 (a) Osmosis (b) Endocytosis  
 (c) Active absorption (d) Passive absorption

42. Most water absorption in plants takes place through [MP PMT 2001]  
 (a) Root cap (b) Root apex  
 (c) Root hair zone (d) Meristematic zone
43.  $\text{Na}^+$ ,  $\text{K}^+$  dependent ATPase activity helps in transport of [DPMT 2004; Odisha JEE 2009]  
 (a)  $\text{K}^+$  inward,  $\text{Na}^+$  outward (b)  $\text{K}^+$  inward only  
 (c)  $\text{Na}^+$  inward only (d)  $\text{K}^+$  outward,  $\text{Na}^+$  inward
44. The continuous excretion of watery substance from stump of a well watered pot plant after cutting off the shoot slightly above the base is due to [Pb. PMT 2004]

Or

Exudation of xylem is due to [RPMT 1995]

- (a) Root pressure (b) Guttation  
 (c) Transpiration (d) Imbibition
45. See the following diagram and identify the process occurring in I, II and III [NCERT]



	I	II	III
(a)	Uniport	Antiport	Symport
(b)	Symport	Co port	Antiport
(c)	Antiport	Uniport	Symport
(d)	Co port	Symport	Antiport

### Factors affecting absorption of water and Ascent of sap

- Which of the following factors affect the absorption of water by roots  
 (a) Soil temperature (b) Soil aeration  
 (c) RH of the atmosphere (d) All the above
- According to Sachs theory, the ascent of sap takes place  
 (a) In xylem ducts with the help of imbibition  
 (b) In the phloem with the help of imbibition  
 (c) In pith with the help of imbibition  
 (d) All of the above
- The force of tension cohesion exceeds root pressure on a  
 (a) Rainy day (b) Foggy morning  
 (c) Sunny day (d) Full moon night

4. Many transplanted seedling may not survive because  
(a) They do not like the new soil  
(b) They do not get required mineral salts  
(c) Most of the root hairs are lost during transplantation  
(d) The leaves get damaged
5. At mid day hours, the xylem sap is in a state of  
(a) Compression (b) Tension  
(c) Relaxation (d) Adhesion
6. Water-logged condition will quickly occur in which type of soil [RPMT 1997]  
**Or**  
Holding capacity is highest in [RPMT 1995]  
(a) Sand (b) Clay  
(c) Gravel (d) Loam
7. When a potted plant is flooded with water, the magnitude of root pressure  
(a) Increases (b) Decreases  
(c) Remains unchanged (d) Becomes negative
6. Position and frequency of stomata can be determined by  
(a) Calculating the loss of water  
(b) Cobalt chloride paper method  
(c) Potometer  
(d) Porometer
7. In both transpiration and evaporation, water is lost in the form of vapour yet they differ, because  
(a) Both transpiration and evaporation are similar but the rate of water loss differs  
(b) Frequency of water loss is different in both of them  
(c) Transpiration is a physical process and evaporation is a physiological process  
(d) Transpiration is a physiological process and evaporation is a physical process
8. Out of the following, which one is the most common type of transpiration  
(a) Foliar (b) Stomatal  
(c) Lenticular (d) Cuticular
9. Which of the following is not the type of transpiration  
(a) Stomatal transpiration (b) Cuticular transpiration  
(c) Lenticular transpiration (d) Endodermal transpiration
10. Maximum transpiration occurs in [MP PMT 1994]  
(a) Mesophytic plants (b) Hydrophytic plants  
(c) Xerophytic plants (d) Algal cells
11. Transpiration facilitates [KCET 2009]  
(a) Electrolyte balance  
(b) Opening of stomata  
(c) Absorption of water by roots  
(d) Excretion of minerals
12. Transpiration is mainly a process of [Odisha JEE 2005]  
(a) Osmotic pressure (b) Imbibition  
(c) Diffusion (d) Respiration
13. Small (Tiny) particle is placed in the pore of stomata what will be happening [MP PMT 2005]  
(a) It will fall on ground  
(b) It will stick to lower epidermis  
(c) It will be accommodate to mesophyll cell  
(d) It will be accommodate in vascular tissues
14. Stomata of CAM plants [CBSE PMT 2003; CPMT 2009; WB JEE 2016]  
(a) Never open  
(b) Are always open  
(c) Open during the day and close at night  
(d) Open during the night and close during the day
15. Transpiration ratio is the ratio of moles of  $H_2O$  transpired/moles of  $CO_2$  fixed. This ratio is measure of [AIIEE Pharmacy 2003]  
(a) The efficiency of guard cells on stomatal movement  
(b) Effectiveness of stomata is maximizing photosynthesis while minimizing water loss  
(c) Distinguishing a xerophyte from a glycophyte  
(d) Stomatal pore size of the leaves

### Transpiration (General) and Stomata

1. The chief role of transpiration in plants is to cause  
(a) Loss of surplus water (b) Cooling of the plant  
(c) Rapid ascent of sap (d) Rapid rise of minerals
2. Guard cells help in [Odisha JEE 2008; CBSE PMT 2009; AFMC 2012]  
(a) Protection against grazing  
(b) Transpiration  
(c) Guttation  
(d) Fighting against infection
3. In woody trees, the exchange of gases between the outer atmosphere and the internal tissue of the stem takes place through [Kerala PMT 2010; NEET 2013]  
(a) Aerenchyma (b) Stomata  
(c) Pneumatophores (d) Lenticels  
(e) Trichomes
4. The number of stomata and epidermal cells in  $1 \text{ mm}^2$  leaf area of lower epidermis of the leaves of X, Y and Z plants are given below. Arrange the plants in decreasing order of their stomatal index

Cell	Numbers of Stomata	Numbers of epidermal cells
X	30	150
Y	60	240
Z	90	400

The correct answer is [EAMCET 2009]

- (a) X, Y, Z (b) Y, Z, X  
(c) Z, Y, X (d) Y, X, Z
5. Force generated by transpiration can create pressure sufficient to lift water even upto the height of [AMU (Med.) 2012]  
(a) 130 feet (b) 130 metre  
(c) 230 feet (d) 230 metre



16. Scotoactive stomata are character of which plants  
[Pt. PMT 1999; RPMT 1999]  
(a) Heliophytes (b) Xerophytes  
(c) CAM Plants (d) All of these
17. Which of the following is not a purpose of transpiration  
[Kerala PMT 2012]  
(a) Helps in absorption and transport in plants  
(b) Prevents loss of water  
(c) Maintains shape and structure of plants by keeping the cell turgid  
(d) Supplies water for photosynthesis  
(e) Cools leaves surface
18. In which type of plants, the stomata remain closed during day time and open during night  
[RPMT 1997; Odisha JEE 2012]  
(a) Photophilous (b) Succulents  
(c) Sciphilous (d) Halophytes
19. A small mesophytic twig with green leaves is dipped into water in a big beaker under sunlight. It demonstrates  
[MP PMT 1997]  
(a) Photosynthesis (b) Respiration  
(c) Transpiration (d) None of the above
20. Which of the following plant is able to show rolling of leaf during mid of the day  
(a) *Nerium* (b) *Melia*  
(c) *Amophila* (d) All the above
21. Which of the following plants economises transpirational loss of water  
(a)  $C_3$  (b)  $C_4$   
(c) Both equally (d)  $C_2$
22. In barley type of plant, the stomata open  
(a) For few hours during day  
(b) During night  
(c) Throughout day and night  
(d) Remain closed
23. Stomatal frequency means  
(a) No. of stomata per unit area of leaf surface  
(b) No. of epidermal cells per unit area of leaf surface  
(c) No. of mesophyll cells in the per unit area of leaf  
(d) None of the above
24. Stomatal index  $I$  is equal to  
(a)  $\frac{S}{E-S}$  (b)  $\frac{S}{E+S}$   
(c)  $\frac{E}{E+S}$  (d)  $\frac{E+S}{E}$
25. In *Vallisneria*, stomata are  
[RPMT 1995]  
(a) Present on upper epidermis of leaf  
(b) Present on lower epidermis of leaf  
(c) Present on both the epidermis of leaf  
(d) Not present
26. In most of the thin leaf mesophytes, the leaf stomata open during day and close during night. It comes under  
(a) Barley type (b) Potato type  
(c) Alfalfa type (d) Bean type
27. Grafted flower is contained in saline water because  
[CPMT 1996]  
(a) Suitable nutrient available to flower  
(b) Flower become fresh in long duration due to less transpiration  
(c) Flower become fresh in long duration due to regulated osmotic pressure of flower cell  
(d) Flower is protected by microbes
28. Sunken stomata are found in leaves of [Odisha JEE 2005]  
(a) *Trifolium* (b) *Lemna*  
(c) *Nerium* (d) *Lilium*
29. Which process is favoured by transpiration  
(a) Photosynthesis (b) Conduction of water  
(c) Stomatal opening (d) All the above
30. Stomata is absent in [CPMT 1996]  
(a) Submerged plants (b) Desert plants  
(c) Floating plants (d) All the above
31. The following percentage of water absorbed by herbaceous plants is lost in transpiration [JIPMER 2002]  
(a) 80 (b) 60  
(c) 90 (d) 40
32. Stomata in angiosperms does not open during  
(a) Noon (b) Twilight  
(c) 11 O'clock (d) At midnight
33. Which of the following plants do not transpire  
(a) Algae  
(b) Fungi  
(c) Submerged hydrophytes  
(d) All the above
34. Stomata open at night and close during day in  
[MP PMT 1999; RPMT 1999]  
Or  
Sunken stomata are adaptations of which category of plants  
[RPMT 1997]  
(a) Xerophytes (b) Gametophytes  
(c) Mesophytes (d) Hydrophytes
35. Lenticular transpiration takes place in  
(a) Fruits (b) Woody stems  
(c) Leaves (d) All the above
36. Which of the following wall of guard cells is thick  
(a) Outer (b) Inner  
(c) Side wall (d) All the three
37. The cells surrounding the stomatal pore are  
(a) Guard cells (b) Subsidiary cells  
(c) Chromophil cells (d) None of the above
38. Select the correct statement(s) pertaining to transpiration process in plants [WB JEE 2016]  
(a) It is a necessary evil for plants  
(b) Loss of water takes place through hydathodes in vapour form  
(c) It may also occur through lenticels  
(d) The process is active during night in  $C_3$  plants

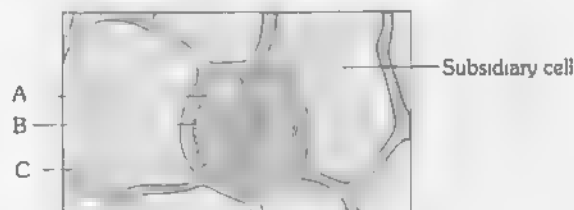
**Factors affecting transpiration**

- Due to low atmospheric pressure, the rate of transpiration will
  - Decrease slowly
  - Decrease rapidly
  - Increase
  - Remain unaffected
- Transpiration is minimised by the deposition of
  - Cellulose
  - Pectin
  - Cutin
  - Mucilage
- Increase in temperature and velocity of wind cause an increase in transpiration initially but later it slows down, because
  - Of closure of stomata
  - Water is not made available
  - The air around the plant becomes humid
  - Of mechanical disturbance
- Which one of the following will reduce the rate of transpiration  
[Manipal MEE 1995; MP PMT 2000; J & K CET 2002]
  - Increase in wind velocity
  - Rise in temperature
  - Increase in water uptake by plants
  - Decrease in light intensity
- Which of the following is produced during water stress and causes closure of stomata [BHU 2002; Odisha JEE 2009]
  - Cytokinin
  - Auxin
  - GA<sub>3</sub>
  - ABA
- The conditions under which transpiration would be most rapid
  - High humidity
  - Excess of water in soil
  - Low humidity, high temperature, guard cells are turgid (open) and moist soil
  - Low velocity of wind
- The transpiration in plants will be lowest  
[BHU 1994; KCET 2006]
  - When there is high humidity in the atmosphere
  - High wind velocity
  - There is excess of water in the cell
  - Environmental conditions are very dry
- Which of the following is not a purpose of transpiration  
[Kerala PMT 2010]
  - Supplies water for photosynthesis
  - Helps in translocation of sugars from source to sink
  - Maintains shape and structure of the plants
  - Cools leaf surfaces
  - Transports minerals from the soil to all parts of the plant
- The rate of transpiration directly depends on
  - Temperature
  - Negative turgor pressure
  - Diffusion pressure deficit
  - Vapour pressure gradient
- Which of the following may be used as an anti-transpirant in plant  
[MP PMT 1995; KCET 2006; RPMT 2006; BHU 2008]
  - Phenyl mercuric acetate
  - Cobalt chloride
  - Mercury
  - Potassium

- Transpiration increase with increase in [MP PMT 2005]
  - Humidity
  - Temperature
  - Minerals
  - Soil moisture
- Under what conditions the rate of transpiration increases by  
[RPMT 1997]
  - Increase of humidity
  - Increase of atmospheric pressure
  - Decrease of temperature
  - Decrease of humidity
- Which would do maximum harm to a tree [KCET 2007]
  - Loss of half of its branches
  - Loss of all of its leaves
  - Loss of all its bark
  - Loss of half of its leaves
- Transpiration can be influenced by interfering with  
[AFMC 1995]
  - Air temperature
  - Epidermis of leaf
  - Guard cell
  - Osmotic pressure
- In the terrestrial habitat which of the following factors affect temperature and rainfall conditions
  - Translocation
  - Transformation
  - Thermo-denaturation
  - Transpiration
- Increase in CO<sub>2</sub> concentration around leaf results in  
[CPMT 1995; CBSE PMT 2000]
  - Rapid opening of stomata
  - Partial closing of stomata
  - Complete closure of stomata
  - There will be no effect on stomatal opening
- Cobalt chloride method was first used by
  - F. Darwin (1912)
  - Stahl (1894)
  - Curtis (1926)
  - Leibeg (1840)
- Which one of the following is not an antitranspirant  
[KCET 2011]
  - PMA
  - BAP
  - Silicon oil
  - Low viscosity

**Mechanism of opening and Closure of stomata**

- Observe the diagram of stomatal apparatus. In which of the following all the three parts labelled as A, B and C are correctly identified [NCERT]



- A - Guard cell, B - Stomatal aperture, C - Microfibril
  - A - Stomatal aperture, B - Guard cell, C - Microfibril
  - A - Microfibril, B - Guard cell, C - Stomatal aperture
  - A - Microfibril, B - Stomatal aperture, C - Guard cell
- Stomata on the surface of the leaf, open by [KCET 2012]
    - Decreasing the solute concentration in the guard cells
    - Increasing the solute concentration in the guard cells
    - Weakening of the cell walls of the guard cells to allow them to stretch
    - Increasing the water potential in the guard cells

3. When stomata closes which of the following events does not occur  
[Odisha JEE 2008]

(a) Guard cell become flaccid  
(b) Sugar is converted to starch  
(c) O.P of the guard cell decreases  
(d) Accumulation of  $O_2$  takes place

4. Select the correct events leading to the opening of the stomata

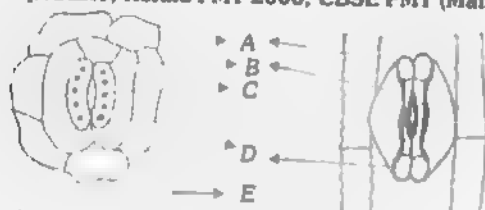
(i) Decline in guard cell solutes  
(ii) Lowering of osmotic potential of guard cells  
(iii) Rise in potassium levels in guard cells  
(iv) Movement of water from neighbouring cells into guard cells  
(v) Guard cells becoming flaccid

[Kerala PMT 2009]

(a) (i) and (v) only (b) (ii), (iii) and (iv) only  
(c) (i), (iii) and (iv) only (d) (ii), (iv) and (v) only  
(e) (iii) and (v) only

5. Choose the correct combination of labelling of stomatal apparatus of dicot and monocot leaves

[NCERT; Kerala PMT 2006; CBSE PMT (Maine) 2010]



(a) A = epidermal cells, B = subsidiary cells, C = chloroplast, D = guard cells, E = stomatal aperture  
(b) A = epidermal cells, B = guard cells, C = chloroplast, D = subsidiary cells, E = stomatal aperture  
(c) A = epidermal cells, B = subsidiary cells, C = chloroplast, D = stomatal aperture, E = guard cells  
(d) A = subsidiary cells, B = epidermal cells, C = chloroplast, D = stomatal aperture, E = guard cells  
(e) A = guard cells, B = epidermal cells, C = stomatal aperture, D = subsidiary cells, E = chloroplast

6. The metal ion involved in the stomatal regulation is or Stomata will open, if there is accumulation of the following element in the guard cells

[JIPMER 1994; CPMT 2004; MP PMT 2005]

Or

Opening and closing of stomata is controlled by

[BHU 2000; Haryana PMT 2005; Odisha JEE 2011]

(a) Iron ( $Fe^{+}$ ) (b) Magnesium ( $Mg^{2+}$ )  
(c) Zinc ( $Zn^{+}$ ) (d) Potassium ( $K^{+}$ )

7. Conversion of starch to organic acid is essential for  
[CBSE PMT 1992, 94]

(a) Stomatal closure (b) Stomatal opening  
(c) Stomatal initiation (d) Stomatal growth

8. Clarification of mechanism of opening and closing of guard cells is based on which of the following theory

[AIPMT (Cancelled) 2015]

(a) Entry and exit of potassium in guard cell  
(b) Photosynthetic process taking place in guard cell  
(c) Starch-sugar conversion  
(d) Transpiration

9. Stomata open during day time because the guard cells  
[CPMT 1993; MP PMT 1993]

(a) Photosynthesize and produce osmotically active sugars or organic acids  
(b) Are thin-walled  
(c) Are bean shaped  
(d) Have to help in gaseous exchange

10. Stomatal opening or closing is due to  
[CBSC PMT 2002; AMU (Med.) 2010; NEET 2017]

(a) Change in the turgidity of guard cells  
(b) The inner wall of each guard cells is thick and elastic  
(c) Cellulose microfibrils of guard cells are oriented radially  
(d) All of the above

11. According the Steward's starch hydrolysis theory, which one of the following is the principle reason for the opening of stomata during daytime  
[KCET 2010]

(a) Influx of  $K^{+}$  ions into guard cells under the influence of ABA hormone  
(b) Conversion of sugar into starch in guard cells  
(c) Efflux of  $K^{+}$  ions from guard cells under the influence of ABA hormone  
(d) Photosynthetic utilization of  $CO_2$  in guard cells

12. Basis of stomatal opening is  
[MP PMT 2004]

Or

A plant cell attains turgidity due to

[Kerala PMT 2004; WB JEE 2011]

Or

Turgor pressure of a plant cell increases due to

[WB JEE 2016]

(a) Exosmosis  
(b) Endosmosis  
(c) Decrease in cell sap concentration  
(d) Plasmolysis of guard cells

13. Which of the following theories is not related to the opening of stomata

(a) Sachs (b)  $K^{+}$  transport  
(c) Korper-Kappa theory (d) Levitt theory

14.  $Na^{+} / K^{+}$  pump in a cell is an example of  
[AMU (Med.) 2010; AIIMS 2012]

(a) Osmosis (b) Diffusion  
(c) Passive transport (d) Active transport

15. Stomatal opening and closing is due to the permeability of the guard cell. This fact was revealed by

(a) Von Mohl (b) Linsbauer  
(c) Lloyd (d) Mansfield

16. Stomata open in the daytime due to  
[Wardha 2005; KCET 2009]

(a) Increase in water potential  
(b) Decrease in water potential  
(c) Decrease in pH  
(d) Light

17. Which of the following statement is not true for stomatal apparatus [NEET (Karnataka) 2013]
  - (a) Guard cells invariably possess chloroplasts and mitochondria
  - (b) Guard cells are always surrounded by subsidiary cells
  - (c) Stomata are involved in gaseous exchange
  - (d) Inner walls of guard cells are thick
18. Stomatal mechanism operates in response to [CPMT 2005]
  - (a) Temperature
  - (b) Light
  - (c) Soil moisture
  - (d) Atmospheric humidity
19. Levitt explanation for stomatal action is due to
  - (a) Increase in sugar content of guard cells
  - (b) Variations in pH value
  - (c) Starch is converted into organic acids
  - (d) Light causes opening and darkness closure
20. The primary osmolyte which causes an opening and closing of stomata is [RPMT 1999]
  - (a) Sugars
  - (b) Starch
  - (c) K-malate
  - (d) Water
21. In guard cells when sugar is converted into starch, the stomatal pore [CBSE PMT 1992]
  - (a) Opens fully
  - (b) Opens partially
  - (c) Closes completely
  - (d) Remains unchanged
22. Which of the following theory gives the latest explanation for the closure of stomata [BHU 2004]
  - (a) ABA theory
  - (b) Munch theory
  - (c) Starch glucose theory
  - (d) Active K<sup>+</sup> transport theory
23. Glycolate induces opening of stomata in [AIIMS 2010]
  - (a) Presence of oxygen
  - (b) Low CO<sub>2</sub> concentration
  - (c) High CO<sub>2</sub> concentration
  - (d) Absence of CO<sub>2</sub>
24. In plants opening of stomata is regulated by [WB JEE 2016]
  - (a) Red light
  - (b) Blue light
  - (c) Far-red light
  - (d) Ultraviolet light
4. From active hydathodes, the water comes out by
  - (a) Osmotic pressure
  - (b) Secreted by force developed within cells themselves
  - (c) By root pressure
  - (d) None of the above
5. Root pressure is due to [Odisha JEE 2011]
  - (a) Passive transport
  - (b) Gravitation
  - (c) Active transport
  - (d) None of these
6. Which one of the following is not related to guttation [KCET 2011]
  - (a) Water is given out in the form of droplets
  - (b) Water given out is impure
  - (c) Water is given out early morning
  - (d) Guttation is of universal occurrence
7. The process of the escape of liquid from the tip of uninjured leaf is called [AIIMS 1998; MP PMT 2012]
  - (a) Evaporation
  - (b) Transpiration
  - (c) Guttation
  - (d) Evapo-transpiration
8. Guttation is the process of elimination of water from plants through or Guttation occurs from or The pores in leaves through which water comes out in the form of droplets are called or A specialized multicellular structure in leaves which excretes water droplets is called as [BHU 1995, 2004; MP PMT 1995, 2010; BVP 2001; MHCET 2002; AFMC 2003, 10; Odisha JEE 2005; CPMT 2005]
  - (a) Stomata
  - (b) Hydathodes
  - (c) Lenticels
  - (d) Wounds
9. Guttation is found mostly in
  - (a) Herbaceous plant
  - (b) Shrubs
  - (c) Wood plants
  - (d) None of these
10. Water is lost in a liquid state in some plants through hydathodes. These hydathodes [KCET 2006]
  - (a) Remain closed at night
  - (b) Remain closed during day
  - (c) Remain always open
  - (d) Do not show any specificity in opening and closing
11. Epithem is
  - (a) Loosely arranged mass of parenchyma in hydathodes
  - (b) Large intercellular spaces of hydathodes
  - (c) Xylem elements of hydathodes
  - (d) Phloem below the air chamber
12. Guttation occurs in [RPMT 1995, 99]
  - (a) Morning
  - (b) Moon
  - (c) Evening
  - (d) Morning 10 O'clock
13. Hydathodes are also called [MHCET 2004]
  - (a) Water stomata
  - (b) Sunken stomata
  - (c) Guard cells
  - (d) Subsidiary cells
14. Which one is not related to transpiration [MP PMT 1997]
  - (a) Regulation of plant body temperature
  - (b) Absorption and distribution of mineral salts
  - (c) Circulation of water
  - (d) Bleeding

### Guttation, Bleeding and Root pressure

1. Guttation is caused due to [KCET 2000, 07; AIIMS 2000; Uttanchal 2001; BHU 2001, 06; Odisha JEE 2009; CBSE PMT (Mains) 2011]
  - (a) Imbibition
  - (b) Osmosis
  - (c) Positive root pressure
  - (d) Transpiration
2. Guttation usually occurs when the plant is put
  - (a) In more saturated atmosphere
  - (b) In more humid soil
  - (c) In dry condition
  - (d) In deserts
3. Which of the following is not a controlled process [BVP 2003]
  - (a) Transpiration
  - (b) Guttation
  - (c) Both (a) and (b)
  - (d) None of the above

15. Which of the following is responsible for passive guttation
- Tension-cohesion of water molecules
  - Activity of epithem tissue
  - Osmotic activity of root hairs
  - Secretion of fluid by mesophyll cells

16. Which of the following is more during the night
- Root pressure
  - Absorption
  - Evaporation
  - Transpiration

### Scientists and Apparatus concerned

- Ultrafiltration theory for permeability of cell membrane was put forth by
  - Traube
  - Ruhland
  - Sachs
  - None of these
- Pressure bomb technique was used by
  - Scholander *et al*
  - Kramer *et al*
  - Dixon *et al*
  - None of the above
- Who proposed the retension pressure theory for the permeability of the membrane
  - Traube
  - Overton
  - Cocking
  - None of these
- Match the theories given in column I with the names of scientists listed in column II. Choose the answer which gives the correct combination of the alphabets

Column - I (Names of theories)		Column - II (Names of scientists)	
A.	Relay pump theory	p.	Stocking
B.	Transpiration cohesion theory	q.	Sir J.C. Bose
C.	Mass flow	r.	Godlewski
D.	Pulsation theory	s.	Dixon and Jolly
		t.	Ernst Munch

[BHU 1999; BVP 2003;

Kerala PMT 2004; KCET 2004; AIIMS 2013]

- A = r; B = s; C = t; D = q
  - A = s; B = r; C = p; D = q
  - A = r; B = q; C = t; D = q
  - A = q; B = p; C = t; D = r
5. Who explained the scotoactive opening of stomata
- Nishida
  - Palls
  - Ehrler
  - None of the above
6. Theory of starch-glucose interconversion was proposed by
- Or
- Enzyme phosphorylase is first of all discovered in guard cells by
- Yin and Tung
  - Zelitch
  - Imamura
  - None of the above
7. For photoactive opening of stomata, the proton transport concept was given by
- Levitt
  - Milborrow
  - Ziegler
  - None of the above

8. According to one vital force theory, ascent of sap is due to active pulsation of innermost layer of cortex. This theory was given by

Or

In plant 'transpiration pull' theory for ascent of sap was first proposed by

[WB JEE 2016]

- J. C. Bose
  - Dixon
  - Strasburger
  - Sachs
9. The scientist, who proposed that production of glycolic acid in guard cells is an important factor in stomatal opening, is
- Kumar
  - Steward
  - Zelitch
  - Lewitt
10. 'Guttation' word is given by
- Fritz
  - Burgerstein
  - Noggle
  - Lewitt
11. Who studied the effect of light on translocation
- De Vries
  - Blackman
  - Williams
  - Hart
12. "There is no translocation at low temperature" has been invented by
- Swanson and Whitne
  - Fenson
  - Spanner
  - Munch
13. Potometer works on the principle of [CBSE PMT 2005]
- Amount of water absorbed equals the amount transpired
  - Osmotic pressure
  - Root pressure
  - Potential difference between the tip of the tube and that of the plant
14. Who had said that "transpiration is a necessary evil"
- [MP PMT 1999]
- Curtis
  - Steward
  - Andersen
  - J. C. Bose
15. Osmoscope is used for
- Measuring OP
  - Measuring TP
  - Measuring psi
  - Demonstration of osmosis
16. Which of the following is used to determine the rate of transpiration in plants [CPMT 1994, 2009; AIIMS 2000; RPMT 2002; BHU 2003; MP PMT 2010, 12]
- Porometer
  - Potometer
  - Auxanometer
  - Tensiometer
17. The term water potential was proposed by [CBSE PMT 2001]
- Bose
  - Dixon
  - Godlewski
  - Slatyer and Taylor
18. Potometer and clinostat are used to study [MHCET 2001]
- Photosynthesis and respiration
  - Transpiration and growth
  - Phototropism and geotropism
  - Transpiration and geotropism
19. Darwin's potometer determine
- Comparison of stomatal and cuticular transpiration
  - Transpiration and absorption ratio
  - Opening of stomata
  - None of these

20. The best vital force theory was proposed by  
 (a) Godlewsky (b) Strasberger  
 (c) Dixon (d) Esau
21. Who has used two bulbs of semipermeable membrane to explain pressure flow theory

Or

Gradient pressure was given as a possible mechanism of translocation of food by

- (a) Munch (b) Jones  
 (c) Spanner (d) Fenson
22. The shoot pressure is measured by  
 (a) G.M. Counter  
 (b) Luxmeter  
 (c) Pressure bomb technique  
 (d) Bomb calorimeter

### Translocation of organic solutes

1. Who proposed that the upward and downward movement of materials take place  
 (a) Sacks (b) Boehm  
 (c) Dixon (d) Curtis
2. The direction of the conduction of food through phloem is [MP PMT 1999]  
 (a) From below upwards  
 (b) From top to bottom  
 (c) From leaves to roots  
 (d) Phloem never conducts food
3. In which form the food is translocated from endosperm to plumule of a fatty seed like castor  
 (a) Fatty acids (b) Fat  
 (c) Glucose (d) Sucrose
4. The figure indicates the ringing or girdling experiment. Bark having phloem is removed. This experiment proves that phloem is the path for translocation of food. In this experiment swollen part of stem has been shown. The possible cause of this swollen is [NCERT]



- (a) Injured parts undergo turgidity  
 (b) A repairing mechanism is taken place  
 (c) Accumulation of water and mineral just above the ring  
 (d) Accumulation of food material just above the ring (As downward movement of food is inhibited)
5. Phloem sap is mainly made of [AMU (Med.) 2012]  
 (a) Water and sucrose  
 (b) Water and minerals  
 (c) Oligosaccharides and hormones  
 (d) None of these

6. The absorption of food in phloem is  
 (a) Basipetal (b) Acropetal  
 (c) Both (a) and (b) (d) None of these
7. The food stored in the ripening fruit is derived from [RPMT 1997]  
 (a) Roots (b) Farthest leaves  
 (c) Nearest leaves (d) Aerial stem
8. In cell transport the difference between permeable transport and bulk transport relates to [BHU 1994]  
 (a) Structure of molecules allowed to pass through  
 (b) Solvent system as well as structure of molecules are applicable  
 (c) Solvent system is applicable  
 (d) Molecular weight of atoms allowed to pass through
9. Sinks are related to [MP PMT 1997]  
 (a) Transport of minerals (b) Stomata  
 (c) Enzymes (d) Phytochrome

10. Consider the following statements with reference to facilitated transport  
 A. Requires ATP energy  
 B. Transport Saturates  
 C. Highly selective  
 D. Requires special membrane properties  
 E. Uphill transport

Of the above statements

[Kerala PMT 2012]

- (a) A, B and C, are relevant but D and E are irrelevant  
 (b) B, C and E, are relevant but A and D are irrelevant  
 (c) C, D and E are relevant but A and B are irrelevant  
 (d) A, D, and E are relevant but B and C are irrelevant  
 (e) B, C and D are relevant but A and E are irrelevant
11. Bidirectional translocation of minerals takes place in [CBSE PMT 1997, 99]

Or

By many evidences, it can be known that the downward movement of food takes place through [DPMT 2003]

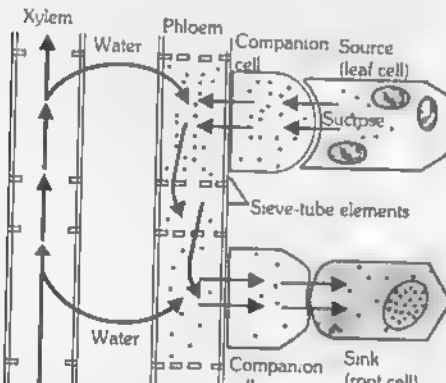
- (a) Xylem (b) Phloem  
 (c) Parenchyma (d) Cambium
12. Leaf photosynthates are transported to other parts of higher plants through [MP PMT 1994, 98]

Or

Food is transported to various parts of the plant through

[AIIMS 1998; BVP 2004]

- (a) Cambial cells (b) Pith cells  
 (c) Xylem cells (d) Phloem cells
13. Which is correct about transport or conduction of substances [AFMC 1994]  
 (a) Organic food moves upwardly through xylem  
 (b) Organic food moves up through phloem  
 (c) Inorganic food moves upwardly and downwardly through xylem  
 (d) Organic food moves upwardly and downwardly through phloem

14. During transport of sugar or amino acid through cell membrane [CBSE PMT 1994]
- $\text{Na}^+$  ions move against the direction of concentration gradient
  - $\text{Na}^+$  ions move in both directions irrespective of its concentration gradient
  - No net  $\text{Na}^+$  ions movement
  - $\text{Na}^+$  ions move in the direction of its concentration gradient
15. By protoplasmic streaming theory, how sugar is translocated from one sieve tube to other
- Diffusion
  - Osmosis
  - Absorption
  - Active transport
16. Supply ends in transport of solute are [MP PMT 1997]
- Green leaves and storage organs
  - Root and stem
  - Xylem and Phloem
  - Hormones and enzymes
17. The movement of materials through the vascular tissue of plants is called [BHU 2002]
- Transpiration
  - Translocation
  - Transcription
  - Transduction
18. According to all Munch's pressure-flow hypothesis, which of the following given conditions would increase the rate of translocation [NCERT]
- 
- A decrease in the photosynthesis
  - An increase in the sucrose production at the source
  - A decrease in phloem unloading at the sink
  - An increase in the humidity in the outside air
19. Active transport of solute in plants refers to flow of solutes against a concentration gradient and therefore requires input of energy. This energy is derived [BHU 1995; AIEEE Pharmacy 2004]
- Always from hydrolysis of ATP
  - Not only from ATP hydrolysis but also from the collapse of a proton motive force
  - Partly from the input from ATP hydrolysis and partly from the collapse of a proton motive force
  - From the different sources depending on the solutes
20. When a plant is girdled or in a ring girdled plant [AIPMT (Cancelled) 2015]
- The root dies first
  - The shoot dies first
  - The root and shoot die at the same time
  - Neither the root nor the shoot will die
21. The carbohydrates synthesized in the leaves are transported through sieve tubes most commonly in the form of [CBSE PMT 1992]
- Or
- Translocation of sugar in flowering plants occurs in the form of [NCERT; CPMT 1998; AMU (Med.) 2006; MP PMT 2006]
- Glucose
  - Triose sugar
  - Sucrose
  - Soluble starch
22. Starch is insoluble in water yet it is accumulated in large quantities in potato because [CPMT 2004]
- It is synthesized in potato tuber itself
  - It is translocated from the leaves to the potato tuber in the form of sugar
  - Soil micro-organism deposit starch in tuber
  - It is useful consumption
23. According to Munch theory, the cause of flow of soluble substances is
- Protoplasmic flow
  - Mass flow due to reduction in turgor pressure
  - Diffusion
  - None of these
24. The translocation of organic solutes in sieve tube members is supported by [CBSE PMT 2006]
- Mass flow involving a carrier and ATP
  - Cytoplasmic streaming
  - Root pressure and transpiration pull
  - P-proteins
25. Who proposed blood like translocation of solutes
- Spanner
  - Munch
  - Williams
  - Jones
26. Organic substances such as sugars are translocated in phloem can be demonstrated by
- Defoliation
  - Ringing the stem
  - Grafting
  - Root pressure
27. Vein loading is the active transport of sugars from [KCET 2012]
- Mesophyll cells to vessels
  - Vessels to mesophyll cells
  - Mesophyll cells to sieve tubes
  - Sieve tubes to mesophyll cells
28. Munch hypothesis is based on [KCET 2007]
- Translocation of food due to TP gradient and imbibition force
  - Translocation of food due to Turgor Pressure (TP) gradient
  - Translocation of food due to imbibition force
  - None of the above

29. Which one of the following elements is necessary for the translocation of sugars in plants  
(a) Iron (b) Manganese  
(c) Molybdenum (d) Boron
30. Which of the following is the main point in disfavour of Munch theory  
(a) Translocation is a pure physiological process  
(b) Translocation is a pure physical process  
(c) Explanation of sugar transport is not given  
(d) None of these
31. Which of the following criteria **does not** pertain to facilitated transport [NEET 2013]  
(a) Uphill transport  
(b) Requirement of special membrane proteins  
(c) High selectivity  
(d) Transport saturation

## NCERT

### Exemplar Questions

1. Which of the following statements does not apply to reverse osmosis [NCERT]  
(a) It is used for water purification  
(b) In this technique, pressure greater than osmotic pressure is applied to the system  
(c) It is a passive process  
(d) It is an active process
2. Which one of the following will not directly affect transpiration [NCERT]  
(a) Temperature  
(b) Light  
(c) Wind speed  
(d) Chlorophyll content of leaves
3. The lower surface of leaf will have more number of stomata in a [NCERT]  
(a) Dorsiventral leaf (b) Isobilateral leaf  
(c) Both a and b (d) None of the above
4. The process of guttation takes place [NCERT]  
(a) When the root pressure is high and the rate of transpiration is low  
(b) When the root pressure is low and the rate of transpiration is high  
(c) When the root pressure equals the rate of transpiration  
(d) When the root pressure as well as rate of transpiration are high
5. Which of the following is an example of imbibition [NCERT]  
(a) Uptake of water by root hair  
(b) Exchange of gases in stomata  
(c) Swelling of seed when put in soil  
(d) Opening of stomata
6. Water potential of pure water at standard temperature is equal to [NCERT; NEET 2017]  
(a) 10 (b) 20  
(c) Zero (d) None of the above

7. Match the followings and choose the correct option  
A. Leaves i. Anti-transpirant  
B. Seed ii. Transpiration  
C. Roots iii. Negative osmotic potential  
D. Aspirin iv. Imbibition  
E. Plasmolyzed cell v. Absorption  
Options [NCERT]  
(a) A-iii, B-iv, C-i, D-ii  
(b) A-i, B-ii, C-iii, D-iv  
(c) A-iii, B-ii, C-iv, D-i  
(d) A-iii, B-ii, C-i, D-iv
8. Mark the mismatched pair [NCERT]  
(a) Amyloplast i. Store protein granule  
(b) Elaioplast ii. Store oils or fats  
(c) Chloroplasts iii. Contain chlorophyll pigments  
(d) Chromoplasts iv. Contain coloured pigments other than chlorophyll  
(e) Leucoplast v. Contains colourless pigments

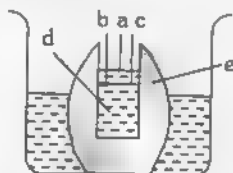
## GT Critical Thinking

### Objective Questions

1. Purple cabbage leaves do not lose their colour in cold water but do so in boiling water because  
(a) Plasma membrane gets inactivated in boiling water  
(b) Hot water can enter the cells readily  
(c) The pigment is not soluble in cold water  
(d) The cell wall is killed in boiling water
2. Primary and secondary active transport both [WB JEE 2008]  
(a) Generate ATP  
(b) Use ATP directly  
(c) Can move solutes against their concentration gradient  
(d) Include the passive movement of glucose molecule
3. When a plant cell is placed in a solution which is hypotonic to the cell sap, which of the following conditions will not apply  
(a) The water potential of the cell sap will rise  
(b) The suction pressure of the cell sap will fall  
(c) The cell will become turgid  
(d) The wall pressure of the cell will fall
4. 0.5 M sucrose solution develops a pressure of 15 bars in an osmometer. Which of the following statements is wrong for such a solution  
(a) That its osmotic potential is - 15 bars  
(b) That its water potential is - 15 bars  
(c) That its pressure potential is - 15 bars  
(d) That its osmotic pressure is + 15 bars

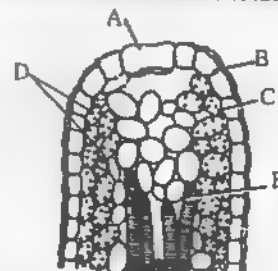


5. A cell when dipped in 0.5 M sucrose solution has no effect but when the same cell will be dipped in 0.5 M NaCl solution the cell will [AFMC 2005]  
 (a) Increase in size (b) Decrease in size  
 (c) Will be turgid (d) Will get plasmolysed
6. In which of the following plants would metabolism be hindered if the leaves are coated with wax on their upper surface  
 (a) *Hydrilla* (b) *Lotus*  
 (c) *Pistia* (d) *Vallisneria*
7. An osmometer is filled with 0.5 M solution of NaCl in water. In which of the following solutions it must be immersed in order to make it shrink [KCET 2012]  
 (a) 0.5 M solution (b) 0.05 M solution  
 (c) Distilled water (d) 0.75 M solution
8. In water-logged soil, plants do not grow properly because [CPMT 1995]  
 (a) The soil is physiologically dry  
 (b) The soil is physiologically wet  
 (c) Due to excessive water  
 (d) Due to shortage of water
9. Turgidity in guard cells is controlled by [MP PMT 2001, 06]  
 (a) Chloride  
 (b) Malic acid  
 (c) Potassium  
 (d) Potassium, chloride and malic acid
10. Root pressure is maximum when [JIPMER 2002; Odisha JEE 2008]  
 (a) Transpiration is high and absorption is very low  
 (b) Transpiration is very low and absorption is high  
 (c) Transpiration is very high and absorption is also high  
 (d) Transpiration and absorption both are slow
11. In which of the following the rate of transpiration is high [MP PMT 2001]  
 (a) CAM plants (b)  $C_3$  plants  
 (c)  $C_3$  and  $C_4$  plants (d)  $C_4$  plants
12. A thin film of water, held by the soil particles under the influence of internal attractive force, is called which of the following water [Pb. PMT 2000; MHCET 2003]  
 (a) Capillary (b) Combined  
 (c) Hygroscopic (d) Gravitational
13. A sufficient atmospheric pressure required to push the water upto the top of tall plants must be [BVP 2003]  
 (a) 2 atm (b) 6 atm  
 (c) 20 atm (d) All of the above
14. Choose the correct combination of labelling of the potato osmoscope experiment [Kerala PMT 2004]



- (a) a-final level, b-dotpin, c-initial level, d-sugar solution, e-potato tuber  
 (b) a-initial level, b-dotpin, c-final level, d-water, e-potato tuber  
 (c) a-final level, b-dotpin, c-initial level, d-water, e-potato tuber  
 (d) a-final level, b-dotpin, c-final level, d-water, e-container  
 (e) a-initial level, b-dotpin, c-final level, d-coconut oil, e-potato tuber

15. Choose the correct combination of labelling of hydathode [Kerala PMT 2004]



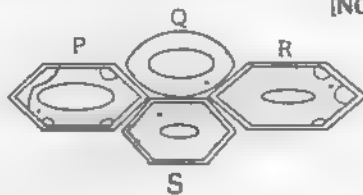
- (a) A-guard cells, B-epithem, C-mesophyll, D-epidermis, E-vasculature  
 (b) A-guard cells, B-epidermis, C-mesophyll, D-epithem, E-vasculature  
 (c) A-ostiole, B-epidermis, C-mesophyll, D-epithem, E-vasculature  
 (d) A-water pore, B-hypodermis, C-mesophyll, D-epithem, E-vasculature
16. The removal of a ring of bark from trunk of a tree eventually kills it, since [BHU 1994]  
 (a) Mineral salts cannot go up  
 (b) Water cannot go up  
 (c) Food does not travel down and roots are starved  
 (d) The exposed part becomes infected with fungi
17. Where does transpiration cohesion pull theory works  
 (a) Active absorption  
 (b) Inactive absorption  
 (c) Active and inactive absorption  
 (d) None of these
18. The speed of water absorption will be greater if  
 (a) The difference between osmotic pressure of soil water and that of xylem vessels is always less  
 (b) The difference between osmotic pressure of soil water and that of xylem vessels is always more  
 (c) The osmotic pressure of soil water is always more than that of xylem vessels  
 (d) The osmotic pressure of soil water is always less than that of xylem vessels
19. During absorption of  $H_2O$  by roots, the  $H_2O$  potential of cell sap is lower than that of [DPMT 2004]  
 (a) Solution outside (b) That of pure  $H_2O$   
 (c) One (d) None of these
20. See the following figure and select the correct option [NCERT]



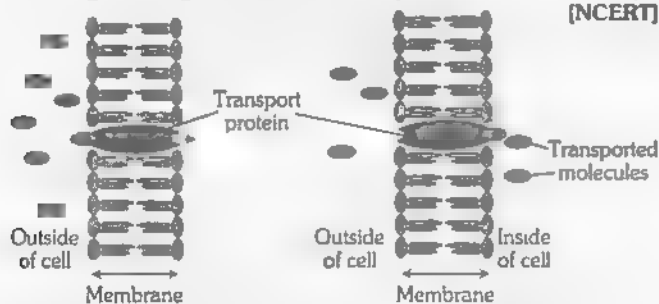
- (a) Water potential has nothing to do with K.E. of water in a solution  
 (b) K.E. of water in A solution = K.E. of  $H_2O$  in B solution  
 (c) K.E. of water in B solution > K.E. of water in A solution  
 (d) Kinetic energy (K.E.) of  $H_2O$  in A solution > K.E. of water in B solution

21. See the following diagram of four plant cells. Select the correct option in which cells would not exert wall pressure [NCERT]

- (a) R and S  
(b) P and R  
(c) Q and S  
(d) P and Q

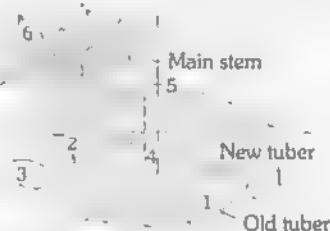


22. The given diagram shows the transportation of materials by [NCERT]



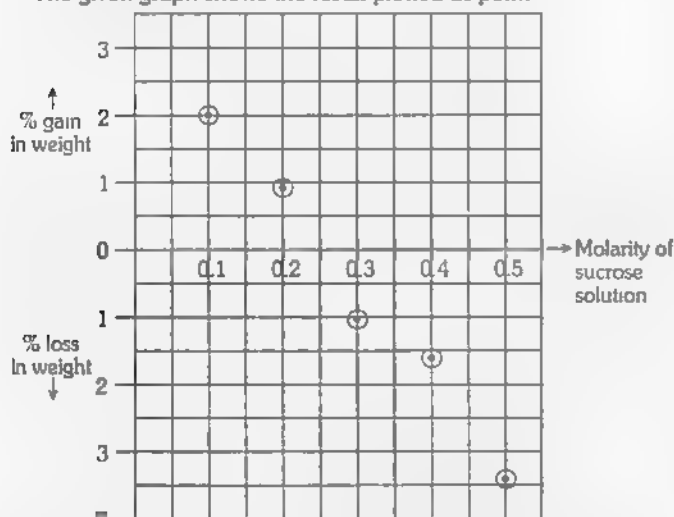
- (a) Secondary active transport (b) Primary active transport  
(c) Facilitated diffusion (d) Simple diffusion
23. The given diagram illustrates a Potato plant forming new tubers. Which route would be taken by most of the food at this time [NCERT]

- (a) 6 → 5 → 4 → 1  
(b) 1 → 4 → 5 → 6  
(c) 6 → 5 → 2 → 3  
(d) 1 → 4 → 2 → 3



24. The experiment given below shows groups of potato disc were weighed and then each group was immersed in one of a series of sucrose solutions. After two hours each group was reweighed and its percentage gain or loss in weight was calculated

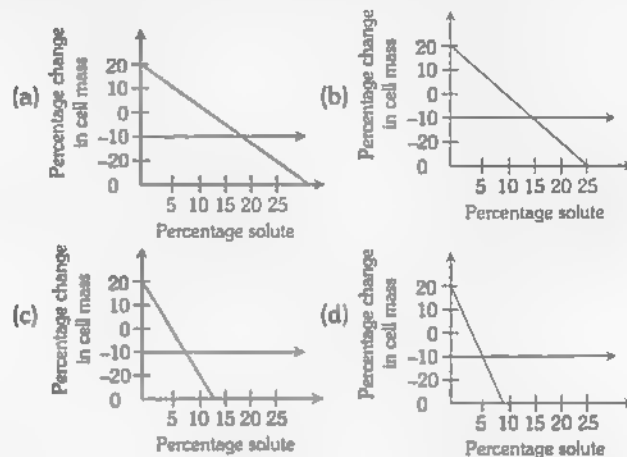
The given graph shows the result plotted as point



From these results it can be concluded that the water concentration of potato cell sap is approximately equivalent to that of a sucrose solution of molarity [NCERT]

- (a) 0.50 (b) 0.35  
(c) 0.25 (d) 0.10

25. The effect of solute concentration on the mass of tissue cells is studied. It is observed from the collected data that the tissue cells were isotonic to 10 % solute concentration. Which of the following graph represents that the cells are isotonic to 10 % solute concentration [NCERT]



26. Which of the following is not correct in mass flow hypothesis [KCET 2015]

- (a) As hydrostatic pressure in the phloem sieve tube increases pressure flow stops and sap is accumulated in phloem  
(b) The sugar is moved bidirectionally  
(c) The sugar which is transported is sucrose  
(d) Loading of the phloem sets up a water potential gradient that facilitates the mass movement in the phloem

27. Water vapour comes out from the plant leaf through the stomatal opening. Through the same stomatal opening carbon dioxide diffuses into the plant during photosynthesis. Reason out the above statements using one of following options [NEET (Phase-I) 2016]

- (a) Both processes cannot happen simultaneously  
(b) Both processes can happen together because the diffusion coefficient of water and  $\text{CO}_2$  is different  
(c) The above processes happen only during night time  
(d) One process occurs during day time and the other at night

28. Specialised epidermal cells surrounding the guard cells are called [NEET (Phase-I) 2016]

- (a) Complementary cells  
(b) Subsidiary cells  
(c) Bulliform cells  
(d) Lenticels

## R Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

- (a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion  
 (b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion  
 (c) If the assertion is true but the reason is false  
 (d) If both the assertion and reason are false  
 (e) If the assertion is false but reason is true
- Assertion : Xylem is principal water conducting tissue.  
Reason : It has been recognised by girdling or ringing experiment. [AIIMS 1995]
  - Assertion : Water and mineral uptake by root hairs from the soil occurs through apoplast until it reaches endodermis  
Reason : Casparian strips in endodermis are suberized. [AIIMS 2003]
  - Assertion : Long distance flow of photoassimilates in plants occurs through sieve tubes.  
Reason : Mature sieve tubes have parietal cytoplasm and perforated sieve plates. [AIIMS 2003]
  - Assertion : Arid areas are not suitable for crops.  
Reason : Antitranspirants are used for planting crops in arid regions.
  - Assertion : Oil will form a film on the top of the water affecting the amount of light entering the water  
Reason : Oil is a polar molecule, and forms hydrogen bonds. [AIIMS 2009]
  - Assertion : Film forming chemical should not be used for checking transpiration.  
Reason : Film forming chemicals interrupt photosynthesis and respiration.
  - Assertion : Stomata are "turgor operated valves"  
Reason : Stomata show reversible turgor changes.
  - Assertion : Wilting occurs due to loss in turgidity.  
Reason : Turgor pressure checks the excessive entry of water into cells.
  - Assertion : Temporary and permanent wilting result in plant death.  
Reason : Plant parts become flaccid in wilting condition.
  - Assertion : Seeds and spores do not lose the viability in unfavourable periods  
Reason : Seeds and spores have high osmotic pressure.
  - Assertion : To counteract the increase in turgour pressure in plant cells, the cell wall produces an equal and opposite pressure, i.e., wall pressure.  
Reason : When plant cells undergo endosmosis, they swell but do not burst. [KCET 2010]

- Assertion : Plasmolysis will be severe if the process is in the order, limiting  $\rightarrow$  incipient  $\rightarrow$  evident.  
Reason : Plasmolysis is exosmosis.
- Assertion : Water absorption is reduced by lowering  $O_2$  tension.  
Reason : The accumulation of  $CO_2$  reduces water absorption.
- Assertion : Upward movement of water is called ascent of sap.  
Reason : Upward movement of water occurs through xylem and phloem.
- Assertion : Plants absorb water mostly by roots.  
Reason : Root cap region participates actively in water absorption.
- Assertion : Field capacity is maximum in loam soil.  
Reason : In water logging condition, the soil has maximum field capacity.
- Assertion : Only vertical movement of water is possible through xylem and tracheids.  
Reason : The xylem ray parenchyma is responsible for the lateral transport of water.
- Assertion : Light is very important factor in transpiration.  
Reason : It induces stomatal opening and darkness closing. Therefore, transpiration increases in light decreases in dark. [AIIMS 1999]
- Assertion : Waxy and cutin coating on plant parts reduce the transpiration.  
Reason : These adaptation are found in xerophytes. [AIIMS 1999]
- Assertion : Water in liquid form reaches to plant surfaces in transpiration process.  
Reason : At plant surface, water changes from liquid to vapour phase.

## Answers

### General

1	a	2	c	3	d	4	b	5	b
6	c	7	b	8	b	9	a	10	a
11	a	12	c	13	a	14	a	15	c
16	d	17	a	18	c	19	c		

### Membranes, osmosis, diffusion, imbibition, plasmolysis and Wilting

1	c	2	c	3	c	4	a	5	d
6	b	7	b	8	d	9	b	10	b
11	c	12	d	13	b	14	a	15	a
16	d	17	b	18	a	19	b	20	c

## 618 Transport in Plants

21	b	22	a	23	a	24	d	25	a
26	b	27	d	28	d	29	b	30	c
31	d	32	c	33	d	34	a	35	a
36	c	37	a	38	d	39	a	40	a
41	d	42	a	43	a	44	b	45	a
46	d	47	b						

### O.P., T.P., I.P., D.P.D and Water potential

1	c	2	b	3	a	4	d	5	a
6	d	7	d	8	b	9	a	10	d
11	c	12	c	13	a	14	d	15	a
16	a	17	d	18	a	19	a	20	b
21	d	22	d	23	d	24	b	25	c
26	c	27	a	28	a	29	d	30	b
31	d	32	a	33	b	34	a	35	d
36	a	37	a	38	a				

### Absorption of water and Ascent of sap

1	a	2	d	3	a	4	a	5	b
6	b	7	d	8	a	9	a	10	d
11	a	12	d	13	a	14	c	15	a
16	d	17	d	18	d	19	a	20	a
21	c	22	c	23	b	24	a	25	c
26	b	27	d	28	d	29	a	30	b
31	d	32	b	33	a	34	a	35	a
36	d	37	c	38	c	39	e	40	c
41	d	42	c	43	a	44	a	45	a

### Factors affecting absorption of water and Ascent of sap

1	d	2	a	3	c	4	c	5	b
6	b	7	b						

### Transpiration (General) and Stomata

1	c	2	b	3	d	4	b	5	b
6	b	7	d	8	b	9	d	10	a
11	c	12	c	13	c	14	d	15	b
16	c	17	b	18	b	19	c	20	c
21	b	22	a	23	a	24	b	25	d
26	c	27	b	28	c	29	b	30	a
31	c	32	d	33	d	34	a	35	b
36	b	37	a	38	ac				

### Factors affecting transpiration

1	c	2	c	3	a	4	d	5	d
6	c	7	a	8	b	9	d	10	a
11	b	12	d	13	d	14	a	15	d
16	b	17	b	18	b				

### Mechanism of opening and Closure of stomata

1	c	2	b	3	d	4	b	5	a
6	d	7	b	8	a	9	a	10	d
11	d	12	b	13	c	14	d	15	b
16	b	17	b	18	b	19	c	20	c
21	c	22	d	23	b	24	b		

### Guttation, Bleeding and Root pressure

1	c	2	a	3	b	4	c	5	c
6	d	7	c	8	b	9	a	10	c
11	a	12	a	13	a	14	d	15	c
16	a								

### Scientists and Apparatus concerned

1	b	2	a	3	a	4	a	5	a
6	a	7	a	8	a	9	c	10	b
11	d	12	a	13	a	14	a	15	d
16	b	17	d	18	d	19	c	20	a
21	a	22	c						

### Translocation of organic solutes

1	d	2	c	3	d	4	d	5	a
6	a	7	c	8	a	9	a	10	e
11	b	12	d	13	d	14	a	15	a
16	a	17	b	18	b	19	a	20	a
21	c	22	b	23	b	24	d	25	b
26	b	27	c	28	b	29	d	30	c
31	a								

### NCERT Exemplar Questions

1	c	2	d	3	a	4	a	5	c
6	c	7	b	8	a				

### Critical Thinking Questions

1	a	2	c	3	d	4	c	5	b
6	b	7	d	8	a	9	d	10	b
11	b	12	c	13	c	14	a	15	c

16	c	17	b	18	b	19	b	20	d
21	b	22	c	23	c	24	c	25	c
26	a	27	b	28	b				

### Assertion and Reason

1	a	2	a	3	a	4	b	5	c
6	d	7	a	8	b	9	a	10	a
11	a	12	b	13	b	14	c	15	c
16	c	17	a	18	a	19	a	20	d

## AS Answers and Solutions

### General

1. (a) The guard cells of monocots (family - Gramineae) are dumbel shaped or elliptical, e.g., Sugarcane.
2. (c) Because loss of water takes place through leaves by transpiration.
4. (b) On removing the ring of bark, phloem and cambium are removed from stem.
5. (b) Loam are sufficiently aerated and have good water holding capacity. Therefore, they are very good for water absorption and growth.
7. (b) Energy is usually provided by ATP or by concentration gradient of ions.
8. (b) Alluvial soil allows percolating the water slowly from it, hence alluvial soil is good soil.
10. (a) Because the water molecules have a great mutual attraction with each other or in other words they have tremendous cohesive power which is sometimes as much as 350 atmospheres.
11. (a) Walls of tracheids and vessels of xylem are made up of lignin and cellulose and have strong affinity for water (adhesion).
13. (a) ATP releases small amount of energy required for building new chemical bonds or chemical reactions in cell.
14. (a) Active absorption takes place by the activity of root itself, particularly root hairs. A root hair cell functions as an osmotic system. Water is absorbed by the root hair due to osmotic differences between soil water and cell sap.
16. (d) Root cap has no function in water absorption because it has no root hair and it is mainly for protection of root tip against any injury.
18. (c) In monocot like sugarcane, maize, etc. due to absence of cambium secondary growth is not found. So removal of bark (phloem) is not possible so that ringing experiment is not possible.
19. (c) The amount of water present in soil against gravitational force is called as field capacity.
3. (c) This type of membrane allow selective passage of solutes along with solvent through them. Many biological membranes such as cell membranes, tonoplast and the membranes surrounding the sub-cellular organelles are selectively permeable.
5. (d) In formalin preserved *Spirogyra* filament, osmosis does not take place.
6. (b) Osmosis is a special type of diffusion or Osmosis through semipermeable membrane.
7. (b) Osmosis is a special type of diffusion of a liquid, when solvent moves through a semipermeable membrane from a place of higher diffusion pressure to a place of lower diffusion pressure.
12. (d) Because in imbibition process, the volume of seed is increased.
13. (b) Plasmolysis is the shrinkage of protoplast of a cell from its cell wall under the influence of a hypertonic solution. The hypertonic solution causes exosmosis or withdrawal of water from the cell. A solution whose osmotic concentration is more than that of another solution or cell sap is called hypertonic solution.
14. (a) In osmosis, movement of water takes place from hypotonic solution to hypertonic solution through semipermeable membrane.
16. (d) Breaking of the seed coat in germinating seeds is due to greater imbibitional swelling of the seed kernel (starch and protein) as compared to seed coverings. Seedling is able to come out of soil due to development of imbibition pressure.
17. (b) Thistle funnel whose mouth is tied with parchment paper is the physiological experiment of osmosis. Parchment paper is a semipermeable membrane which allows all solvents but no solute to pass through them.
18. (a) Plasmalemma allows selective passage of solutes along with solvent, through them.
19. (b) Plasma membrane shows selectively permeable membrane hence it controls passage of water and some solutes in and out of the cell
20. (c) Peel of *Tradescantia* leaf is generally used for the demonstration of plasmolysis in laboratory.
22. (a) When a cell is placed in distilled water, water start moving into the cell by the process of endosmosis, and cell become turgid.
23. (a) If a cell is placed in isotonic solution, there is no net changes of water between the cell and the solution.
24. (d) Proteins are the strongest imbibants of water, starch less strong, cellulose being the weakest. That is why proteinaceous pea seeds swell more than the starchy wheat seeds.

25. (a) At noon the rate of transpiration is maximum. The rate of water absorption is less due to shrinkage of roots and depletion of water around the root hairs.
26. (b) Because of exosmosis.
27. (d) The water is first imbibed by walls of root hairs and then absorbed and helps in rupturing of seed coat (made up of cellulose). Materials capable of imbibition such as proteins and cellulose in living beings cause seeds to swell when they are placed in water.
28. (d) Removal of large molecule from cell is also known as exocytosis.
29. (b) Due to exosmosis, the protoplasm shrinks and leaves the cell wall and thus cell becomes flaccid, which is called plasmolysed cell and this phenomenon is called plasmolysis. Thus exosmosis leads to plasmolysis.
30. (c) Consumption and production of solvent does not take place in osmosis. It is the just migration of solvent from the hypotonic to hypertonic solution hence volume of solvent remains same.
31. (d) Selectively permeable membrane such as membrane of root hairs and tonoplast membrane of vacuole allows certain substances more readily than semipermeable membranes.
32. (c) In case exosmosis continues, the protoplasm shrinks from the cell wall. The phenomenon is called plasmolysis (flaccid in appearance). Plant part or in the cells due to scarcity of water are termed as wilting.
33. (d) If the plasmolysed cell (flaccid cell) is placed in hypotonic solution then endosmosis occurs, which makes the cell again turgid and this is known as deplasmolysis.
34. (a) Due to exosmosis.
35. (a) Because water contents of potato comes out from the potato tuber or due to exosmosis.
37. (a) Due to adsorption of water molecules into wooden furniture it get swelled.
38. (d) Due to exosmosis (plasmolysis), the protoplasm shrinks and leaves the cell wall and thus cell becomes flaccid which is called plasmolysed cell.
39. (a) Xylem is responsible for transport of water. If xylem is blocked, plant will undergo wilting due to the lack of proper transport of water.
40. (a) It is the temporary drooping down of leaves and young shoots due to loss of turgidity during noon. At this time the rate of transpiration is maximum. Temporary wilting is corrected only after the rate of transpiration decreases in the afternoon accompanied by replenishment of water around the root hairs.
41. (d) Rapid transpiration causes mid-day leaf water deficit (temporary wilting). If such condition continues for sometime, permanent water deficit permanent wilting may develop, which causes injury to plants.
42. (a) Because of excessive fertilizers concentration are increased and water comes out of the plant cells due to exosmosis.
43. (a) Because cell wall of rhizoids and assimilatory filament cells work as semipermeable membrane.
44. (b) Imbibition pressure can be defined as the maximum pressure that an imbibant will develop when it is completely soaked in pure water. In Gram seeds (proteins) also have high imbibition capacity.
45. (a) Diffusion may be defined as, "movement of particles of a matter due to their own kinetic energy".
46. (d) It is the migration of solvent through a semipermeable membrane to keep the concentration equal.
47. (b) Plasmolysis takes place in 3 stages  
(A) Limiting plasmolysis (1st stage)  
(B) Incipient plasmolysis (Mid stage)  
(C) Evident plasmolysis (Last stage)

### O.P., T.P., I.P., D.P.D and Water Potential

1. (c) The amount by which D.P. of solution is lower than that of its pure solvent, is called diffusion pressure deficit (D.P.D.).
3. (a) 1 M solution of a solute at normal temperature and pressure has water potential - 23 bars, hence 0.1 M solution will have water potential - 2.3 bars.
9. (a) Water potential of cell protoplasm is equal but opposite in sign to D.P.D. Water potential of pure water is zero and addition of solute in it, decreases it.
10. (d) In a fully turgid cell, O.P. is equal to T.P. and thus D.P.D. is zero.
11. (c) Water potentials of the given cells are  

$$\psi = \psi_s + \psi_R$$

$$A = -0.87 + 0.44 = -0.43$$

$$B = -0.92 + 0.34 = -0.58$$

$$C = -0.68 + 0.27 = -0.41$$
 As water moves from greater water potential to less, root hair, root cortical and leaf mesophyll cells are C, A, B respectively.
15. (a) The hydrostatic pressure developed inside the cell on the cell wall due to endosmosis is called turgor pressure. It is responsible for growth of young cells.
16. (a) The pure water, at atmospheric pressure, has zero water potential. The addition of any solute particles reduces the free energy of water. Thus the water potential will be negative.
18. (a) Osmotic potential or solute potential ( $\psi_s$ ) are always in negative values and pressure potential ( $\psi_p$ ) is usually positive. Water potential of a solution is always less than zero or has negative value.
20. (b) The opening and closing of stomata depends on the concentration of solutes in the guard cells (the main component of the solute concentration in guard cells is  $K^+$ ). When the concentration of solutes,  $K^+$  ion guard cells increases, their osmotic pressure increases. In other words, their water potential decreases. As a result of this, they absorb water from their surrounding epidermal cells, their turgidity increases.

22. (d) When T.P. is negative, DPD will be more than OP  
D.P.D. of a cell mainly depends upon OP
25. (c)  $\psi = P + \pi$ ; where  $\psi$  = Water potential,  $P$  = Osmotic pressure,  $\pi$  = Osmotic potential
29. (d) A bar is a pressure unit which equals 14.5 lb/in<sup>2</sup>, 750 mm Hg or 0.987 atm.
31. (d) When  $OP = WP$   
 $WP = TP$   
 $OP = TP$   
i.e., cell has no further capacity to absorb any water.
32. (a) Water moves from higher water potential (Less negative) to lower water potential (more negative).
33. (b) Because of establishment of equilibrium.
34. (a) Due to endosmosis and suction pressure of the cell. Cell will get its original shape and size.
35. (d) In case of fully turgid cell, the net movement of water into the cell is stopped. The cell is in equilibrium with the water outside. The water potential in such case will be zero (0).
36. (a) Osmotic pressure of a solution is equivalent to the pressure, which must be exerted upon it to prevent the flow of solvent into it across a semipermeable membrane.
38. (a) Osmotic Pressure – Turgor Pressure = Diffusion Pressure Deficit (DPD).
- Absorption of water and Ascent of sap**
6. (b) The absorption of water still occurs when concentration of outer soil water is more than root hair cell sap.
7. (d) Cohesion is the attraction between the molecules of the same substances. e.g., water-water transpiration pull: A tension or negative pressure develops in the water column present in tracheary elements. It exerts an upward pull over the water column called transpiration pull.
9. (a) Physical theories believe that ascent of sap is a physical phenomenon.
12. (d) Tracheary elements are the part of xylem.
15. (a) In mycorrhiza, fungal member helps in absorption of mineral and water.
23. (b) Because inorganic salts are absorbed with water.
25. (c) When the concentration of the soil solutes is low, the absorption of water is increased. This is due to diffusion of water inside the absorbing cell. This is because water moves from high concentration (of water) to low concentration (of water). So when the soil has less solute the water concentration must be more and thus absorption of water by the cell will be more at the relatively high content of water.
27. (d) Ascent of sap takes place by root pressure which develops by transpiration pull
28. (d) A plant with deep and elaborate root system can absorb more water. Moreover, the number of root hairs will be more in a highly branched and elaborate root system, thus its more surface area will be in contact with water.
29. (a) When concentration of outer soil water is more than root hair cell sap, under such conditions exosmosis should occur, but it has been seen that water is still absorbed against concentration gradient.
30. (b) It occurs in the form of film coating smaller soil particle. It is also called growth water.
31. (d) Force for absorption of water is generated in the cells of root itself. Osmotic and non-osmotic forces are involved in active water absorption.
32. (b) Sap moves up the stem through the lumen of xylem vessels and tracheids.
34. (a) Diffusion of water from its pure state or dilute solution into a solution or stronger solution when the two are separated by a semipermeable membrane is termed as osmosis. In plants water supply is due to osmosis.
36. (d) In angiosperms, sap moves up the stem through the lumen of xylem vessels and tracheids and not through their walls.
38. (c) A cell takes up water due to its suction pressure, (DPD)  
 $SP = OP - TP$ .
40. (c) Water column remains intact despite gravitational pull because water molecules have a strong cohesion force amongst them due to presence of hydrogen bonds. Cohesion force provides a tensile strength to water column. It has a value of 45–207 atm.
41. (d) Here roots play passive role in water absorption, i.e., forces responsible for absorption of water are not generated in roots, but in upper parts of the plant, i.e., transpiration pull.
42. (c) Water absorbing part of the young roots is root hair zone. It lies between 2–10 cm. from the root tip. Root hairs are tubular extension of epidermal cells.
43. (a) ATPase may itself catalyze a direct transport of  $K^+$ , or a  $Na^+/K^+$  exchange pump.
44. (a) Root pressure is caused by absorption of water through root hairs.
- Factors affecting absorption of water and Ascent of sap**
1. (d) Soil temperature, soil aeration, relative humidity (R.H.), amount of soil water and transpiration are factors affect the absorption.
2. (a) According to imbibitional theory (Sachs 1879), water moves upward in the stem through the imbibitional activity of the walls of the xylem vessels to be responsible for the ascent of sap.
3. (c) Because transpiration rate is very high in sunny day.
6. (b) Clay particles are tiny and sticky in nature, hence holding capacity is highest in clay soil.
7. (b) Increased amount of water in the soil beyond a certain limit results in poor aeration of the soil which retards metabolic activities of root cells like respiration and hence, the rate of water absorption is also retarded and magnitude of root pressure is very low (about 2 atm).

**Transpiration (General) and Stomata**

1. (c) It brings rapid translocation of water in the plant to compensate the loss of water during transpiration.

4. (b) Stomatal index (SI) =  $\frac{S}{S+E} \times 100$

Plant	Numbers of stomata (S)	No. of epidermal cells (E)	SI
X	30	150	16.6
Y	60	240	20.0
Z	90	400	18.3

So, the arrangement of plants in decreasing order of their stomatal index is, Y, Z, X.

6. (b) Cobalt chloride paper method is used to compare rate of transpiration on two surfaces of leaf. Cobalt chloride is blue in anhydrous state. In contact with water vapour it turns pink.
7. (d) Transpiration occurs in plants, only from living cells. Evaporation occurs from any free surface. Both from living and nonliving surface.
8. (b) Maximum loss of water by plant takes place through stomata.
9. (d) Endodermis is internal layer which is not related with transpiration.
10. (a) About 98 percent of the water absorbed by land plants evaporates from the aerial parts and diffuses into the atmosphere.
16. (c) CAM plants are succulent or fleshy plants. The stomata of succulent plants remain closed during day and open during night to avoid water loss (scotoactive stomata).
18. (b) Such stomata are known as scotoactive stomata.
20. (c) Plants growing in dry conditions (xerophytes) develop some characters in leaves so as to reduce rate of transpiration like rolling of leaf during mid of the day e.g., *Amophila*.
22. (a) Barley type stomata open only for a few hours in the day time, otherwise they remain closed throughout the day and night. e.g., Cereals.
23. (a) Number of stomata per square cm is 1000 – 60,000 in different plant species. Stomatal frequency of trees and shrubs is higher than those of herbs.
24. (b)  $S$  = Number of stomata per unit area.  
 $E$  = Number of epidermal cells per unit area.
25. (d) Because *Vallisneria* is an aquatic plant.
29. (b) It is assumed that the upward movement of water through the plant requires the occurrence of transpiration.
33. (d) Because algae and fungi are not differentiate in root, stem and leaves and transpiration takes place from these parts. Submerged hydrophytes possess vestigial stomata hence transpiration are absent.

34. (a) Such stomata are known as scotoactive stomata. This is a mechanism to reduce water loss due to transpiration. When they are situated in grooves and sometimes protected by hairs, the rate of transpiration is further decreased. Such adaptations are found in xerophytes. These are found in plants like *Opuntia*, *Aloe*, *Bryophyllum* etc.
35. (b) Lenticels are the areas in the bark of woody plants which are filled with loosely arranged cells known as complementary cells. Loss of water vapour through lenticels is called lenticular transpiration.
36. (b) The outer wall of these cells is thin and inner wall is thick.
37. (a) Each stoma is bordered by two specialized epidermal cells called 'guard cells' which are generally kidney shaped or bean shaped but in grasses, guard cells are dumb-bell shaped.
38. (ac) Transpiration is a necessary evil for plants (water is continuously lost during the process even during stress but is important for ascent of sap and metabolism). Transpiration also occurs by lenticels

**Factors affecting transpiration**

1. (c) At low atmospheric pressure at high altitudes, the rate of transpiration is increased. The rate of transpiration is inversely proportional to the atmospheric pressure.
3. (a) Increase in temperature leads to opening of stomata even at night but within a certain physiological range. Again very high temperature leads to closing of stomata even in day (mid-day closure). Similarly very high wind velocity decreases transpiration by lowering temperature.
4. (d) Light affects the rate of transpiration directly by opening of stomata. In the absence of light or decrease in light intensity the stomata are closed and the stomatal transpiration is completely checked.
5. (d) In the case of hydroactive control abscisic acid (ABA) plays an important role in the closure of stomata, when ever there is shortage of water ABA is synthesized resulting in the closure of stomata.
6. (c) Increase in the temperature of the air decreases the humidity of the air and therefore more water is vapourised and lost from the transpiring surface. When soil is moist means availability of water are sufficient, stomata will open thus rate of transpiration increases.
7. (a) If the atmosphere is very humid and relatively saturated its capacity to absorb water is low and the rate of transpiration is slowed down.
9. (d) Transpiration depends upon difference in vapour pressure of internal atmosphere of leaf and external environment (i.e., V.P. gradient) and it is, therefore, that no transpiration occurs when stomata are fully open but relative humidity is 100%.



11. (b) Temperature directly effects the transpiration. As the temperature rises so does the transpiration. Temperature in its turn is effected by light.
12. (d) If the atmosphere is humid, it reduces the rate of transpiration. When the air is dry, the rate of transpiration increases.
13. (d) Loss of half of the leaves of tree provide maximum harm to tree because rate of transpiration slows down and metabolic activity is also lowered but the plants remains alive in stressed condition.
16. (b) Mansfield (1965) reported that removal of  $CO_2$  maintained stomatal opening even in the dark. Conversely, the stomata close in light if the  $CO_2$  concentration is increase.
22. (d) As per "Active  $K^+$  transport mechanism" accumulation of  $K^+$  ions occurs in the guard cell during the day in response to light. It increases the turgidity of guard cells consequently stoma opens. During night, ions move out of the guard cells into surrounding epidermal cells consequently guard cells become flaccid and stomata close.
23. (b) Light causes photosynthesis which lead to reduction in  $CO_2$  concentration  $\rightarrow$  synthesis of glycolate  $\rightarrow$  oxidation of glycolate  $\rightarrow$  ATP synthesis  $\rightarrow$  activation of  $K^+$  pump  $\rightarrow$  movement of  $K^+$  in guard cell  $\rightarrow$  movement of water into guard cells  $\rightarrow$  swelling of guard cell  $\rightarrow$  opening of stomata.

### Mechanism of opening and Closure of stomata

6. (d) When  $K^+$  ions into the guard cells, stomata open and when  $K^+$  ions out, stomata close.  $K^+$  ion is necessary to maintain the turgidity of guard cells of stomata.
9. (a) Stomata open during day time because the guard cells prepare osmotically active substances by photosynthesis. As a result, their osmotic pressure increases and their turgor pressure increases due to endosmosis.
10. (d) Stomata in angiosperms open and close due to change of turgor pressure in cells are turgid state the stomatal aperture opens and when guard cells are in flaccid state the stomatal aperture closes.
12. (b) Endosmosis increases the turgidity of guard cells. The osmotic inflow of water into a cell enables a plant cell to attain turgidity.
13. (c) Korper – kappe theory its related to tissue system (Root and shoot).
15. (b) Linsbauer (1916) suggested that the removal of  $CO_2$  by photosynthesis causes opening of stomata by changing the permeability of the guard cells to different kinds of solutes and guard cells are more permeable when the stomata are closed.
17. (b) Sometimes, a few epidermal cells in the vicinity of the guard cells become specialised in their shape and size and are known as subsidiary cells.
21. (c) In the evening leaf photosynthesis stops. Carbon dioxide concentration increases in the leaf interior. It results in decrease in pH. Glucose is phosphorylated to form glucose 6-phosphate. It is changed to glucose 1-phosphate from which starch is synthesised.  
Starch does not exert any osmotic potential and therefore, guard cells lose water to nearby epidermal cells. Their turgidity falls and the stomatal pore closes.
2. (a) Guttation is most common in plants growing in moist warm soil with their aerial parts surrounded by humid air.
4. (c) Exudation of liquid from the water pore or stoma is due to the development of a positive hydrostatic (root pressure) pressure in the xylem present in the vein ending. The pressure forces the liquid out through the hydathode.
7. (c) Guttation, is the process in which water drops come outside by margins of leaves by hydathodes.
8. (b) Hydathodes are usually found on the margins and tips of the leaves. Each hydathode consists of a group of loosely arranged achlorophyllous or colourless and parenchymatous cells called epithem.
11. (a) Guttation is found in herbaceous plant e.g., Garden nasturtium (*Tropaelum najas*), oat (*Avena Sativa*), Barley (*Hordeum vulgare*) and colocasia (*Colocasia antiquorum*) etc. growing in moist, warm soil and under humid conditions.
12. (a) In guttation drops of liquid come out of the edges of leaves during night and early mornings.
14. (d) Bleeding takes place through injured organs of plants.
16. (a) In night, root pressure will be maximum because in night transpiration is zero.

### Scientists and Apparatus concerned

1. (b) W. Ruhland (1912) and Hoffman (1925) described that, small pores are found on membranes the molecules which are small in size than pores of membrane are only passed through these membranes.
2. (a) Scholander et.al. (1965) ever the first to measure the tension directly by using pressure chamber method.
3. (a) Traube (1867) proposed his "Haftdruck" or retention pressure theory. According to him the permeation of solutes through a membrane depended on their relative greatness of affinity towards the membrane substance as compared to that of water.

5. (a) Some stomata open during night and remain closed during the day time and found in lower surface. This type of stomatal opening is called scotoactive type. This mechanism was explained by Nishida (1963).
6. (a) Yin and Tung (1948). Enzyme phosphorylase in guard cells are responsible for starch glucose interconversion
7. (a) It incorporates good points of scarrh's classical pH theory and active  $K^+$  transport theory.
9. (c) Zelitch (1963) proposed that stomata open due to production of glycolic acid by photorespiration in guard cells under low concentration of  $CO_2$ .
11. (d) Hartt and his coworkers (1964) proposed that the movement of assimilates of a leaf can depend upon radiant energy
12. (a) Swanson and Whitney (1953) reported that translocation out of the leaf was highly sensitive to temperature. Optimum temperature for translocation.
13. (a) The rate of absorption of water is approximately equal to the rate of transpiration
17. (d) Slatyer and Taylor (1960). According to him water potential is the chemical potential of water which is equivalent to DPD with negative sign.
18. (d) Potometer used for transpiration and clinostat used for geotropism.
20. (a) Godlewsky (1884) proposed Relay pump theory
21. (a) Munch mass flow or pressure flow Hypothesis : According to Munch (1930), the translocation of organic solutes takes place through phloem along a gradient of turgor pressure from the region of higher conc. of soluble solutes i.e., supply end to the region of lower conc. i.e., consumption end.
22. (c) Scholander et al. (1965) were the first to measure the tension directly by using pressure chamber method or pressure bomb technique.

### Translocation of organic solutes

1. (d) According to curtis upward conduction of food also takes place through phloem This view is based upon ringing experiments.
2. (c) Food (carbohydrates) is translocated from leaves to roots and storage organs along the phloem in the form of sucrose. Downward translocation from leaves to stem and roots.
3. (d) Translocation of solutes mostly occurs in form of sucrose.
9. (a) It is the long distance movement of organic substances from the source or supply end (region of manufacture or storage) to the region of utilization or sink.
15. (a) The movement of the molecules of gas, liquids and solutes from the region of higher concentration to the region of lower concentration is known as diffusion.
20. (a) Girdling : Removal of bark (phloem) in a ring-like manner is called as girdling. Due to this the root will not get food and die.
23. (b) *Munch mass flow* : This theory is based on difference in osmotic pressure in leaf mesophyll cells and root cells

29. (d) Boron is highly essential for translocation of sugar. Translocation of sucrose occurs in the form of sucrose – borate complex.
30. (c) Ziegler (1956) believes that the diffusion of sugars from the mesophyll cells to the sieve tubes may occur against a concentration gradient

### Critical Thinking Questions

1. (a) The intensity of the colour increases with the increase in temperature because at higher temperature the semi-permeability of the plasma membrane is gradually lost.
3. (d) If a cell is placed in hypotonic solution, water start moving into the cell by the process of endosmosis and cell become turgid.
4. (c) The pressure potential is usually positive.
5. (b) Sucrose is non-ionizing substance whereas  $NaCl$  is ionizing and osmotic pressure of a solution of ionizing substance is greater than that of equimolar concentration of a non-ionizing substance.
6. (b) Covering of the leaf surface with wax will stop cuticular transpiration, block stomata, stop stomatal transpiration and gaseous exchange on that surface.
8. (a) In water-logged soil, plants are unable to absorb water, thus they do not grow properly.
9. (d)  $K^+$  are balanced by organic anions i.e., malate and some  $Cl^-$  ions are also taken in to neutralize a small percentage of  $K^+$ , this mechanism is controlled the turgidity of guard cells.
10. (b) Stephentiales (1727) coined the term root pressure. Root pressure is developed when rate of water absorption is more than the rate of transpiration.
11. (b) For  $C_3$  plants the ratio is 500–800. It shows that  $C_4$  plants transpire less and are more efficient in conserving water than most of  $C_3$  plants.
12. (c) The water is held tightly around the soil particles due to cohesive forces. Hygroscopic water can not be easily removed by the plants. This type of water in soil is not available to plants.
13. (c) Taller plants like *Eucalyptus* need higher pressure to raise the water up. While the value of root pressure ranges from 2.5 atmospheres. A pressure of about 20 atm. is required to raise the water to tops of tall trees.
16. (c) Ringing or girdling experiment was first performing by Hartig (1937). This experiment suggests that in absence of phloem, downward translocation of food is stopped.
17. (b) According to passive absorption theory, the forces responsible for absorption of water originate not in the cells of roots but in the cells of transpiring shoots.
18. (b) Water is absorbed by the root hair due to osmotic differences between soil water and cells sap.
19. (b) During absorption of water by roots the water potential of cell sap is lower than that of pure water. Due to higher osmotic pressure of water in the root hair, the water from soil passes into the root hair.

### Assertion and Reason

1. (a) Hartig performed ringing experiment to show path of water through xylem. Xylem is basic tissue for conduction of water in higher plants. It has vessels and tracheids which are well adapted for water translocation.
2. (a) In plants, usually maximum water uptake is found in the root hair zone, as this part has the maximum surface area due to the presence of root hairs. These root hairs also withdraw from interspaces, which are not in contact with epiblemma of the root. Whereas, the zone of mature cells cannot absorb water because of the presence of impermeable and suberised surface layer.
3. (a) Sieve tubes are the conducting elements of phloem (a permanent vascular tissue which conducts organic food in plant body) which are elongated tubular channels formed by end to end union of numerous cells. The septa between individual sieve tube cells or sieve elements are bulged out. They are called sieve plates possessing a number of perforations (sieve pores or sieve pits) and helps in conduction of food.
4. (b) In arid and unirrigated areas crop plants cannot be grown because of excessive transpiration and reduced water availability. Substances that reduce the rate of transpiration are called antitranspirants. e.g., ABA. Antitranspirants will maintain a favourable internal water balance even in cases of very low water availability. It will allow farmers to grow crop profitably in unirrigated areas and help foresters to plant trees even in extreme arid or desert areas.
5. (c) Oil is a nonpolar molecule, which means that it does not form hydrogen bonds with water and therefore, does not dissolve.
6. (d) Film forming chemicals check transpiration by forming a thin film on the transpiring surface. They are sufficiently permeable to carbon dioxide and oxygen to allow photosynthesis and respiration but prevent movement of water vapours through them. These such chemicals can be used as antitranspirants.
7. (a) Many plant movements are produced due to reversible turgor changes in the cells. The opening and closing of stomata are caused by gain and loss of turgidity by their guard cells. They are hence often called "turgor operated valves".
8. (b) Flowers, young stems and other softer organs are able to maintain their form due to turgidity or TP (turgor pressure). In case of loss of turgidity, the shoots droop down and the leaves show wilting. Turgor pressure (pressure potential or hydrostatic pressure) keeps a check on the excessive entry of water into cells.
9. (e) In case of loss of turgidity, the shoots droop down and the leaves show wilting. In wilting the individual cells of leaves and other softer parts become flaccid, due to loss of water from their interior. In temporary wilting, plants gain their turgidity when they are given water. If the soil does not obtain water periodically, the recovery may be only partial or it may not occur at all. The latter condition is known as permanent wilting.
10. (a) A high osmotic pressure has been found to protect the plants against drought and frost injury. Seeds and spores are similarly able to pass through the unfavourable periods due to high osmotic pressure (or low solute potential).
11. (a) Turgor pressure is the pressure which develops in the confined part of an osmotic system due to osmotic entry of water into it. It is also called hydrostatic pressure or pressure potential. The force exerted by the cell wall over the protoplast is called wall pressure. Normally wall pressure is equal and opposite to turgor pressure except when the cell becomes flaccid.
12. (b) Shrinkage of the protoplast of a cell from its cell wall under the influence of a hypertonic solution is called plasmolysis. Hypertonic solution causes exosmosis or withdrawal of water from the central vacuole of cell. The pressure on the wall is simultaneously reduced and the elastic wall contracts causing a reduction in cell size. This is first stage of plasmolysis called limiting plasmolysis. Initially the protoplast withdraws itself from the corners. This stage is known as incipient plasmolysis. Due to continued exosmosis, protoplast shrinks further and withdraws from the cell wall except at one or a few points. It is known as evident plasmolysis. Cells cannot survive in such case.
13. (b) The accumulation of  $\text{CO}_2$  in the soil appears to have a greater inhibitory effect on water absorption than do lowered oxygen tensions. An increase in  $\text{CO}_2$  causes an increase in the viscosity of protoplasm and a decrease in the roots permeability to water thereby bringing about a retardation in water absorption.
14. (c) Sap is water with dissolved ingredients. The upward movement of water from roots towards the tips of stem branches and their leaves is called ascent of sap. It occurs through the tracheary elements of xylem.
15. (c) Plants have the potentiality to absorb water through their entire surface right from root, stem, leaves, flowers, etc. However, as water is available mostly in the soil, only the underground root system is specialized to absorb water. In roots, the most efficient region of water absorption is the root hair zone.
16. (c) The optimum or maximum amount of water retained per unit dry weight of soil after the stoppage of gravitational flow is called field capacity. It is 25-35% in common loam soils. Soil moisture beyond field capacity produces water logging.
17. (e) Although vessels and tracheids are oriented in the plant in a vertical direction with respect to their long axis and water movement is predominantly in this direction, lateral water movement does take place. Numerous pits through which water may pass perforate the side walls of vessel elements and tracheids. The xylem ray parenchyma greatly facilitates the lateral transport of water and nutrients.
18. (a) Light induces opening of stomata and increase the temperature, both these factor help in increase of transpiration, while darkness causes closure of stomata and reduces the rate of transpiration. Transpiration depends on closure and opening of stomata.
19. (a) Waxy coating, thick cuticle, sunken stomata, hairy surface reduce transpiration and are characters of xerophytes which grow in places where water is not available in much quantity.
20. (d) The intercellular spaces of the transpiring organ is almost saturated with water vapours. When the stomata are open the water vapours are drawn from the substomatal cavities to the outside air due to high DPD of the latter. This increases the DPD of the substomatal air which draws more water vapours from the intercellular spaces. The latter in turn get water vapours from the wet walls of mesophyll cells.

## Transport in Plants

## Self Evaluation Test

- Imbibition process involves
  - Both diffusion and capillary action
  - Only diffusion
  - Only capillary action
  - None of the above
- In the process of osmosis in the cell
  - Both cell wall and protoplasm will act as a membrane
  - Entire protoplast act as a membrane
  - Only outermost layer of protoplasm act as a membrane
  - Only cell wall act as a membrane
- Osmotic pressure is highest in [RPMT 1992]
  - Xerophytes
  - Lithophytes
  - Halophytes
  - Mesophytes
- In which part of the plant water is stored [CPMT 1996]
  - Roots
  - Stem
  - Leaves
  - Bark
- Which of the following is done during ringing experiment [CPMT 2010]
  - Bark is removed
  - Pith is removed
  - Xylem is removed
  - All of these
- The most abundant intracellular cation is [NEET 2013]
  - $K^+$
  - $Na^+$
  - $Ca^{++}$
  - $H^+$
- Which of the following statements is/are not true
  - In CAM plants stomata open during dark and remain closed during the day
  - Role of  $Na^+$  in stomatal opening is now universally accepted
  - The water potential of root cells is higher than the water potential of soil
  - Capillarity theory is the most accepted theory of water movement through plants
  - The walls of xylem vessels made up of ligno-cellulose have strong affinity for water molecules

[Kerala PMT 2008]

  - B, C and E only
  - B, C and D only
  - A, B and C only
  - B and C only
  - A and E only
- Match the column I and with column II
 

Column I	Column II
1. Bulliform cells	A. Stomata
2. Guard cells	B. Aerating pore
3. Lenticel	C. Accessory pore
4. Subsidiary cell	D. Isobilateral leaf

[Manipal 2005]

  - 1-D, 2-A, 3-B, 4-C
  - 1-A, 2-D, 3-B, 4-C
  - 1-D, 2-B, 3-C, 4-A
  - 1-A, 2-B, 3-C, 4-D
- Guttation only occurs in
  - Hydrophytes
  - Mesophytic herbs
  - Mangroves
  - Marshy plants
- Which is the most important precaution to be observed in finding out the rate of transpiration through Ganong's potometer
  - A broad leaf plant need to be selected
  - The experimental shoot should be obliquely cut
  - The shoot should be cut under water
  - Apparatus to be filled with water
- In the resting state of the neutral membrane, diffusion due to concentration gradients, if allowed, would drive [CBSE PMT 2004]
  - $Na^+$  into the cell
  - $Na^+$  out of the cell
  - $K^+$  into the cell
  - $K^+$  and  $Na^+$  out of the cell

## Answers and Solutions

- |    |   |   |   |   |   |   |   |    |   |
|----|---|---|---|---|---|---|---|----|---|
| 1  | a | 2 | c | 3 | c | 4 | c | 5  | d |
| 6  | a | 7 | b | 8 | a | 9 | b | 10 | c |
| 11 | a |   |   |   |   |   |   |    |   |
- (c) Outermost layer of cell i.e., plasma membrane acts as semipermeable membrane.
  - (c) Because halophytes are the plants of saline habitat.
  - (b) All plants do not show guttation. It is restricted to about 345 genera of herbaceous and some woody plants. e.g., Garden Nasturtium, Oat, Balsam, Tomato etc.
  - (c) The shoot should be cut under water because prevent air from entering the vessels.



## Chapter 4.2

# Mineral Nutrition

Organisms require many organic and inorganic substances to complete their life cycle. All such substances which they take from outside constitute their nutrition. On the basis of their nutritional requirements, organisms can be classified into heterotrophs and autotrophs.

All non-green plants and animals, including human beings, are heterotrophs. Autotrophic green plants obtain their nutrition from inorganic substances which are present in soil in the form of minerals, which are known as mineral elements or mineral nutrients and this nutrition is called mineral nutrition.

### Essential mineral elements

An essential element is defined as 'one without which the plant cannot complete its life cycle, or one that has a clear physiological role'. Therefore, in 1939 Arnon and Stout proposed the following characters for judging the criteria of essentiality of an element in the plant :

- (1) The element must be essential for normal growth and reproduction, which cannot proceed without it.
- (2) The requirement of the element must be specific and cannot be replaced by another element.
- (3) The requirement must be direct that is, not the result of any indirect effect *e.g.*, for relieving toxicity caused by some other substance

Essential elements are divided into two broad categories, based on the quantity in which they are required by plants. Macro-elements and micro-elements. Their ionic forms are respectively called macronutrients and micronutrients. Mineral salts dissolved in soil solution are constantly passing downwards along with percolating (gravitational) water. The phenomenon is called leaching. Leaching is more in case of anions.

### Macronutrients (Macroelements or major elements) :

Which are required by plants in larger amounts (Generally present in the plant tissues in concentrations of 1 to 10 mg per gram of dry matter). Of the non-essential functional elements, silicon and sodium often occur in the range of macroelements. Macroelements are usually involved in the synthesis of organic molecules and development of osmotic potential.

**Micronutrients (Microelements or minor elements or trace elements) :** Which are required by plants in very small amounts, *i.e.*, in traces (equal to or less than 0.1 mg per gram dry matter). Cobalt, vanadium, aluminium and nickel, may be essential for certain plants. Microelements are mostly involved in the functioning of enzymes, as cofactors or metal activators. The usual concentration of essential elements in higher plants according to D.W. Rains (1976) based on the data of Stout are as follows :

Table : 4.2-1

Elements	% of dry weight
Macronutrients	
Carbon	45
Oxygen	45
Hydrogen	6
Nitrogen	1.5
Potassium	1.0
Calcium	0.5
Magnesium	0.2
Phosphorus	0.2
Sulphur	0.1
Micronutrients	
Chlorine	0.01
Iron	0.01
Manganese	0.005
Boron	0.002
Zinc	0.002
Copper	0.0001
Molybdenum	0.0001

## Plant analysis

**Ash analysis :** The plant tissue is subjected to a very high temperature (550-600°C) in an electric muffle furnace and is reduced to ash. The plant ash left behind forms a very small proportion of plants dry weight ranging from 2 to 10% only. Analysis of plant ash shows that about 92 mineral elements are present in different plants. Out of these, 30 elements are present in each and every plant and rest are in one or other plant. Out of these 30 elements, 16 elements are necessary for plants and are called essential elements.

**Solution culture (Hydroponics) :** In this method plants are grown in nutrient solutions containing only desired elements. To determine the essentiality of an element for a particular plant, it is grown in a nutrient medium that lacks or is deficient in this element.

The growing of plants with their roots in dilute solutions of mineral salts instead of soil led to increased understanding of plant nutrition. This cultivation of plants by placing the roots in nutrient solution is called hydroponics. Probably the first recorded use of soilless culture was by Woodward in 1699. By 1860, the culture solution technique was modernized by Sachs and he showed the essentiality of nitrogen for plant growth.

Another significant worker for studying the essentiality of elements was Knop (1865). The method of growing plants in aqueous nutrient solutions as employed by Sachs and Knop is used experimentally and commercially today and known as hydroponic culture. Now a days a chelating agent  $\text{Na}^2\text{-EDTA}$  (Disodium salt of ethylene diamine tetra acetic acid. EDTA (Ethylene diamine tetra-acetic acid) is a buffer which is used in tissue cultures is added

**Sand culture :** Here plants are grown in inert sand + nutrient solution. Main advantage is that roots get natural environment and proper aeration.

**Aeroponics :** In this practice, plants are grown with their roots bathed in nutrients mist. This method has been successfully used in growing Citrus and olive.

## Major role of nutrients

Various elements perform the following major roles in the plants :

**Construction of the plant body :** The elements particularly C, H and O construct the plant body by entering into the constitution of cell wall and protoplasm. They are, therefore, referred to as framework elements. Besides, these (C, H and O) N, P and S, Mg and Fe also enter in the constitution of protoplasm. They are described as protoplasmic elements.

**Maintenance of osmotic pressure :** Various minerals present in the cell sap in organic or inorganic form maintain the osmotic pressure of the cell.

**Maintenance of permeability of cytomembranes :** The minerals, particularly  $\text{Ca}^{++}$ ,  $\text{K}^+$  and  $\text{Na}^+$  maintain the permeability of cytomembranes.

**Influence the pH of the cell sap :** Different cations and anions influence on the pH of the cell sap.

**Catalysis of biochemical reaction :** Several elements particularly Fe, Ca, Mg, Mn, Zn, Cu, Cl act as metallic catalyst in biochemical reactions.

**Toxic effects :** Minerals like Cu, As, etc. impart toxic effect on the protoplasm under specific conditions.

**Balancing function :** Some minerals or their salts act against the harmful effect of the other nutrients, thus balancing each other.

## Specific role of macronutrients

The role of different elements is described below :

(1) **Carbon, hydrogen and oxygen :** These three elements, though can not be categorised as mineral elements, are indispensable for plant growth. Carbon, hydrogen and oxygen together constitute about 94% of the total dry weight of the plant. Carbon is obtained from the carbon dioxide present in the atmosphere. It is essential for carbohydrate and fat synthesis. Hydrogen and oxygen would be obtained from water which is absorbed by the plants from the soil. Some amount of oxygen is also absorbed from the atmosphere.

### (2) Nitrogen

**Source :** The chief source of nitrogen for green plants is the soil. It is absorbed mainly in the form of nitrate ions ( $\text{NO}_3^-$ ). The major sources of nitrate for the plants are sodium nitrate, potassium nitrate, ammonium nitrate and calcium nitrate.

**Functions :** Nitrogen is an essential constituent of proteins, nucleic acids, vitamins and many other organic molecules as chlorophyll. Nitrogen is also present in various hormones, coenzymes and ATP etc. It plays an important role in protein synthesis, respiration, growth and in almost all metabolic reactions. It also intensifies colouration in apple.

### Deficiency symptoms

- (i) Impaired growth
- (ii) Yellowing of leaves (appearing first in older leaves) due to loss of chlorophyll, i.e., chlorosis.
- (iii) Development of anthocyanin pigmentation in veins, sometimes in petioles and stems.
- (iv) Delayed or complete suppression of flowering and fruiting.

**Excessive supply** of nitrogen produces following symptoms :

- (i) Increased formation of dark green leaves.
- (ii) Poor development of root system.
- (iii) Delayed flowering and seed formation.

### (3) Phosphorus

**Source :** Phosphorus is present in the soil in two general forms, organic and inorganic. Organic compounds are decomposed and phosphorus is made available to plants in inorganic form. Soil solution contains phosphorus in inorganic forms as the phosphate ions obtained as  $\text{H}_2\text{PO}_4^-$  and  $\text{HPO}_4^{2-}$ . When pH is low phosphate ions are present in the form of  $\text{H}_2\text{PO}_4^-$ . When pH is high, phosphate ions are represented in  $\text{HPO}_4^{2-}$ .

**Functions**

(i) Phosphorous is present abundantly in the growing and storage organs such as fruits and seeds. It promotes healthy root growth and fruit ripening by helping translocation of carbohydrates.

(ii) It is present in plasma membrane, nucleic acid, nucleotides, many coenzymes and organic molecules as ATP.

(iii) Phosphorus plays an indispensable role in energy metabolism i.e., hydrolysis of pyrophosphate. Thus it is required for all phosphorylation reactions.

**Deficiency symptoms**

(i) Leaves become dark green or purplish.

(ii) Sometimes development of anthocyanin pigmentation occurs in veins which may become necrotic (Necrosis is defined as localised death of cells).

(iii) Premature fall of leaves.

(iv) Decreased cambial activity resulting in poor development of vascular bundles.

(v) Sick leaf disease.

**(4) Sulphur**

**Source :** Sulphur is present as sulphate  $\text{SO}_4^{2-}$  in mineral fraction of soil. In industrialized areas, atmospheric sulphur dioxide ( $\text{SO}_2$ ) and sulphur trioxide ( $\text{SO}_3$ ; in low concentration) may be important sources of sulphur nutrition.

**Functions**

(i) Sulphur is a constituent of amino-acids like cystine, cysteine and methionine; vitamins like biotin and thiamine, and coenzyme A.

(ii) It increases the nodule formation in the roots of leguminous plants. It favours soluble organic nitrogen and there is decrease in the quantity of soluble nitrogen with its increase.

(iii) The characteristic smell of mustard, onion and garlic is due to the presence of sulphur in their volatile oils.

(iv) Sulphur in plants is required in stem and root tips and young leaves. It is remobilised during senescence.

**Deficiency symptoms**

(i) Leaves remain small and turn pale green i.e., symptoms of chlorosis. Chlorosis affects young leaves more because of immobile property of the sulphur. The young leaves develop orange, red or purple pigment.

(ii) Leaf tips and margins roll downwards and inwards e.g., tobacco, tea and tomato.

(iii) Delayed flowering and fruiting.

(iv) Apical growth is retarded whereas premature development of lateral buds starts.

(v) The tea yellow disease is caused in tea plants.

(vi) Decrease in stroma lamellae and increase in grana stacking.

(vii) Increase in starch and sucrose accumulation, and decrease in reducing sugars.

**(5) Potassium**

**Source :** Source of  $\text{K}^+$  to the plants is inorganic compounds like potassium sulphate, potassium nitrate, etc. Potassium is usually present in sufficient amount in clay soils. It contains approximately 0.3 to 6.0 percent of whole plant. In seeds, it is found in less amount.

**Functions**

(i) It differs from all other macronutrients in not being a constituent of any metabolically important compound

(ii) It is the only monovalent cation essential for the plants.

(iii) It acts as an activator of several enzymes including DNA polymerase.

(iv) It is essential for the translocation of photosynthates, opening and closing of stomata, phosphorylation, synthesis of nucleic acid and chlorophyll.

It takes part in the formation of cell membrane and it is also responsible for maintenance of turgidity of cells.

**Deficiency symptoms**

(i) Mottled chlorosis followed by the development of necrotic areas at the tips and margins of the leaves.

(ii)  $\text{K}^+$  deficiency inhibits proteins synthesis and photosynthesis. At the same time, it increases the rate of respiration.

(iii) The internodes become shorter and root system is adversely affected.

(iv) The colour of leaves may turn bluish green.

(v) Widespread blackening or scorching of leaves may occur as a result of increased tyrosinase activity.

(vi) Rosette or bushy habit of growth may be seen in plants.

Destruction of pith cells of tomato and increased differentiation of phloem elements

**(6) Calcium**

**Source :** It is absorbed by the plants in the form of  $\text{Ca}^{2+}$  from calcium carbonate etc. It occurs abundantly in a non-exchangeable form such as anorthite ( $\text{CaAl}_2\text{Si}_2\text{O}_8$ ). Much of the exchangeable calcium of the soil is absorbed on to the surface of clay micelle.

**Functions**

(i) It is necessary for formation of middle lamella of plants where it occurs as calcium pectate.

(ii) It is necessary for the growth of apical meristem and root hair formation.

(iii) It acts as activator of several enzymes, e.g., ATPase, succinic dehydrogenase, adenylate kinase, etc.

(iv) Along with  $\text{Na}^+$  and  $\text{K}^+$  it maintains the permeability of plasma membrane.

(v) It is involved in the organisation of spindle fibres during mitosis.

(vi) It antagonises the toxic effects of  $\text{Na}^+$  and  $\text{Mg}^{++}$ .

It is essential for fat metabolism, carbohydrate metabolism, nitrate assimilation and binding of nucleic acids with proteins

**Deficiency symptoms**

- (i) Ultimate death of meristems which are found in shoot, leaf and root tips.
- (ii) Chlorosis along the margins of young leaves, later on they become necrotic
- (iii) Distortion in leaf shape.
- (iv) Roots poorly developed or may become gelatinous.
- (v) Young leaves show malformation and leaf tips becomes hooked.
- (vi) Its deficiency checks flowering and causes the flowers to fall early.
- (vii) Potato tubers become small and malformed.

**(7) Magnesium**

**Source :** Magnesium occurs in the soil in the form of magnesite ( $MgCO_3$ ), dolomite ( $MgCO_3, CaCO_3$ ), magnesium sulphate ( $MgSO_4$ ) and as silicates. It is absorbed from the soil in the form of (Exchangeable cation) ions ( $Mg^{++}$ ). It is easily leached and thus become deficient in sandy soils during rainy season.

**Functions**

- (i) It is an important constituent of chlorophyll.
- (ii) It is present in the middle lamella in the form of magnesium pectate.
- (iii) It plays an important role in the metabolism of carbohydrates, lipids and phosphorus.
- (iv) It acts as activator of several enzymes
- (v) It is required for binding the larger and smaller subunits of ribosomes during protein synthesis.

**Deficiency symptoms**

- (i) Interveneal chlorosis followed by anthocyanin pigmentation, eventually necrotic spots appear on the leaves. As magnesium is easily transported within the plant body, the deficiency symptoms first appear in the mature leaves followed by the younger leaves at a later stage.
- (ii) Stems become hard and woody, and turn yellowish green.
- (ii.) Depression of internal phloem and extensive development of chlorenchyma.

**Specific role of micronutrients****(1) Iron**

**Source :** It is present in the form of oxides in the soil. It is absorbed by the plants in ferric ( $Fe^{3+}$ ) as well as ferrous ( $Fe^{2+}$ ) state but metabolically it is active in ferrous state. Its requirement is intermediate between macro and micro-nutrients.

**Functions**

- (i) Iron is a structural component of ferredoxin, flavoproteins, iron prophyrin proteins (Cytochromes, peroxidases, catalases, etc.)
- (ii) It plays important roles in energy conversion reactions of photosynthesis (phosphorylation) and respiration.
- (iii) It acts as activator of nitrate reductase and aconitase.
- (iv) It is essential for the synthesis of chlorophyll.

**Deficiency symptoms**

- (i) Interveneal chlorosis particularly in younger leaves, the mature leaves remain unaffected
- (ii) It inhibits chloroplast formation due to inhibition of protein synthesis.
- (iii) Stalks remain short and slender.
- (iv) Extensive interveneal white chlorosis in leaves.
- (v) It may develop necrosis aerobic respiration severely affected
- (vi) In extreme deficiency scorching of leaf margins and tips may occur.

**(2) Manganese**

**Source :** Like iron, the oxide forms of manganese are common in soil. However, manganese dioxide (highly oxidised form) is not easily available to plants. It is absorbed from the soil in bivalent form ( $Mn^{++}$ ). Oxidising bacteria in soils render manganese unavailable to plants at pH ranging from 6.5 to 7.8.

**Functions**

- (i) It acts as activator of enzymes of respiration (malic dehydrogenase and oxalosuccinic decarboxylase) and nitrogen metabolism (nitrite reductase).
- (ii) It is required in photosynthesis during photolysis of water.
- (iii) It decreases the solubility of iron by oxidation. Hence, abundance of manganese can lead to iron deficiency in plants.

**Deficiency symptoms**

- (i) Chlorosis (interveneal) and necrosis of leaves.
- (ii) Chloroplasts lose chlorophyll, turn yellow green, vacuolated and finally perish
- (iii) 'Grey speck disease' in oat appears due to the deficiency of manganese, which leads to total failure of crop.
- (iv) 'Marsh spot's in seeds of pea.
- (v) Deficiency symptoms develop in older leaves.

**(3) Copper**

**Source :** Copper occurs in almost every type of soil in the form of complex organic compounds. A very small amount of copper is found dissolved in the soil solution. It is found in natural deposits of chalcocopyrite ( $CuFeS_2$ ).

**Functions**

- (i) It activates many enzymes and is a component of phenolases, ascorbic acid oxidase, tyrosinase, cytochrome oxidase.
- (ii) Copper is a constituent of plastocyanin, hence plays a role in photophosphorylation
- (iii) It also maintains carbohydrate nitrogen balance.

**Deficiency symptoms**

- (i) Both vegetative and reproductive growth are reduced.
- (ii) The most common symptoms of copper deficiency include a disease of fruit trees called 'exanthema' in which trees start yielding gums on bark and 'reclamation of crop plants', found in cereals and legumes.
- (iii) It also causes necrosis of the tip of the young leaves (e.g., *Citrus*). The disease is called 'die back'.



(iv) Carbon dioxide absorption is decreased in copper deficient trees.

(v) Wilting of entire plant occurs under acute shortage.

(vi) Grain formation is more severely restricted than vegetative growth.

#### (4) Molybdenum

**Source :** It is available to the plants mostly as molybdate ions. It is required in extremely small quantities by plants.

#### Functions

(i) Its most important function is in nitrogen fixation because it is an activator of nitrate reductase.

(ii) It is required for the synthesis of ascorbic acid.

(iii) It acts as activator of some dehydrogenases and phosphatases.

#### Deficiency symptoms

(i) Mottled chlorosis is caused in the older leaves as in nitrogen deficiency, but unlike nitrogen-deficient plants, the cotyledons stay healthy and green.

(ii) It is also known to inhibit flowering, if they develop, they fall before fruit setting.

(iii) It leads to drop in concentration of ascorbic acid.

(iv) Its deficiency causes 'whiptail disease' in cauliflower and cabbage. The leaves first show an interveinal mottling and the leaf margins may become gray and flaccid and finally brown.

#### (5) Zinc

**Source :** Zinc occurs in the soil in the form of ferromagnesian minerals like magnetite, biotite and hornblende. Increase in soil pH decreases the availability of zinc.

Bivalent form of zinc ( $Zn^{++}$ ) is exchangeable and is readily available in the soil. Plants require this mineral only in traces and its higher concentrations are highly toxic.

#### Functions

(i) It is required for the synthesis of tryptophan which is a precursor of indole acetic acid—an auxin.

(ii) It is a constituent of enzymes like carbonic anhydrase, hexokinase, alcohol dehydrogenase, lactic dehydrogenase and carboxypeptidase.

(iii) It is required for metabolism of phosphorus and carbohydrates.

(iv) Zinc also appears to play an important role in protein synthesis because in its absence there is substantial increase in soluble nitrogenous compounds.

#### Deficiency symptoms

(i) The first symptom appears in the form of interveinal chlorosis of the older leaves, starting at the tips and the margins.

(ii) Growth becomes stunted due to formation of smaller leaves and shortened internodes. Reduced stem growth is due to less synthesis of auxin.

(iii) The leaves become distorted and sickle shaped and get clustered to form rosettes. This effect is known as 'little leaf disease'.

(iv) In maize, zinc deficiency produces 'white bud disease' which leads to greatly reduced flowering and fruiting as well as poorly differentiated root growth.

(v) Its deficiency causes khaira disease of rice and mottled leaf of apple, *Citrus* and walnut.

#### (6) Boron

**Source :** Boron is present in the soil in very small amounts. It appears in exchangeable soluble and nonexchangeable forms in the soil  $BO_3^{3-}$  or  $B_4O_7^{2-}$ . It is absorbed from the soil as boric acid ( $H_3BO_3$ ) and tetraborate anions.

#### Functions

(i) It facilitates the translocation of sugars.

(ii) It is involved in the formation of pectin.

(iii) It is also required for flowering, fruiting, photosynthesis and nitrogen metabolism.

(iv) Boron is required for uptake and utilisation of  $Ca^{2+}$ , pollen germination, seed germination and cell differentiation.

(v) It regulates cellular differentiation and development.

#### Deficiency symptoms

(i) The first major symptom of boron deficiency is the death of shoot tip because boron is needed for DNA synthesis

(ii) Generally flowers are not formed and the root growth is stunted

(iii) The leaves develop a thick coppery texture, they curve and become brittle.

(iv) Some of the physiological diseases caused due to boron deficiency are internal cork of apple, top rot of tobacco, cracked stem of celery, browning of cauliflower, water core of turnip, hard fruit of *Citrus* and heart rot of sugar beets and marigold. These diseases can be cured by application of small doses of sodium tetraborate in the soil.

(v) Its deficiency checks the cell division of cambium but continues cell elongation.

#### (7) Chlorine

**Source :** It is absorbed from the soil as chloride ions. Hence, it is rarely supplied as fertilizer.

#### Functions

(i) It is required for photolysis of water during photosynthesis in photosystem-II.

(ii) In tobacco, it increases water volume inside the cell and also regulates carbohydrate metabolism.

(iii) With  $Na^+$  and  $K^+$ , chlorine helps in determining solute concentration and anion cation balance in the cells.

(iv) It is essential for oxygen evolution in photosynthesis.

#### Deficiency symptoms

(i) The deficiency symptoms of chlorine consist of wilted leaves which later become chlorotic and finally attain a bronze colour

(ii) Roots become stunted or thickened and club shaped and fruiting is reduced.

(iii) Photosynthesis is also inhibited.

**Critical elements :** Macroelements which become commonly deficient in the soils are called critical elements. They are in number—N, P and K most fertilisers contain critical elements. They are called complete fertilisers.

### Mechanism of absorption of mineral elements

Plants obtain minerals from soil where these are dissolved in soil solution or are present adsorbed to colloidal clay particles.

□ Mineral salt absorption is **independent** of water absorption.

□ Maximum mineral salt absorption occurs by **zone of elongation**. No mineral salt absorption occurs by root hair zone. Mineral salt absorption occurs directly by cells of epiblemma and not by root hair.

□ Mineral salts are absorbed mostly in form of ions, i.e., anions and cations

Various theories have been proposed to explain the mechanism of mineral salt absorption and can be placed under the following two categories.

(1) **Passive absorption** : Absorption of ions without the use of metabolic energy is known as passive absorption. This type of absorption is carried out by purely physical forces.

Briggs and Robertson (1957) demonstrated the passive absorption of ions by root system. They showed :

(i) Mineral salt absorption is not affected by temperature and metabolic inhibitors.

(ii) Rapid uptake of ions occurs when plant tissues are transferred from a medium of low concentration to high concentration.

Some of the important theories explaining the mechanism of passive absorption of minerals are given below :

**Mass flow hypothesis** : According to Hylmo (1953, 1955), the ion absorption increases with increase in transpiration. The ions have been considered to move in a mass flow with water from the soil solution through the root and eventually to the shoot. The theory was supported by Kramer (1956), Russel and Barber (1960), etc. Later, Lopushinsky (1960) using radioactive  $P^{32}$  and  $Ca^{45}$ , has supported this experiment.

**Simple diffusion hypothesis** : According to this hypothesis, if the concentration of solutes inside the plant is lower than the soil, the mineral ions are thought to migrate into the root by simple diffusion. As a result, a state of equilibrium is reached. The part of plant cell or tissue that permits free diffusion is sometimes called outer space. The apparent volume that accommodates these ions has been referred to by some workers as apparent free space. The accumulation of ions in the cell against concentration gradient can not be explained by this concept

**Facilitated diffusion hypothesis** : According to this concept, the ions are transported across the membrane by a carrier protein. When the ions enter the cell through protein channels and not through the lipid layer the phenomenon is called facilitated diffusion.

**Ion exchange hypothesis** : According to this view the ions adsorbed to the cell surface are exchanged from the external medium. A cation is exchanged for a cation and anion for anion. If a particular ion is absorbed by the plant, in exchange it offers  $H^+$  or  $OH^-$  ions which are made available by the dissociation of water molecule

There are two theories to explain the mechanism of ion exchange.

(i) **Contact exchange theory** : According to this theory, ions are not completely static, they are always oscillating around their absorption surface and when the oscillation volume of the ions on the roots and on the colloidal particles overlap each other, ion exchange occurs. An equilibrium is maintained between the dissolved fractions as any depletion in the soil solution is covered by movement of ions.

(ii) **Carbonic acid exchange theory** : In this case,  $CO_2$  released by roots during respiration reacts with water to produce carbonic acid which dissociates into hydrogen ions and bicarbonate ions. Hydrogen ion exchanges itself with the cations adsorbed on the colloidal particles and the bicarbonate ions release the adsorbed anions to supply both anions and cations nearby.

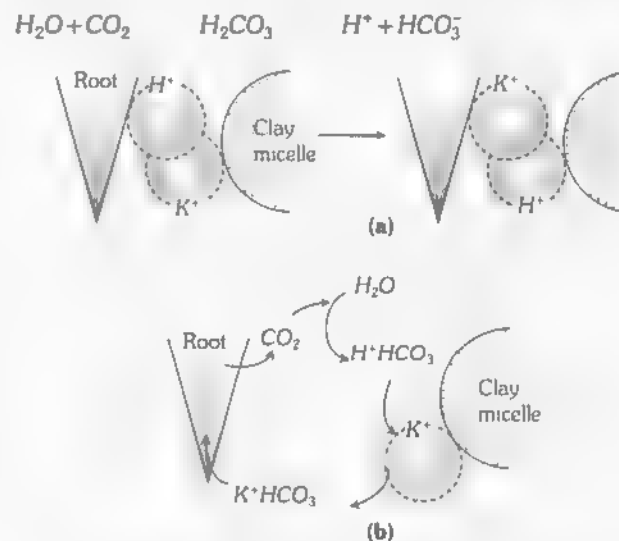


Fig : 4.2-1 Diagrammatic representation of (a) The contact-exchange theory and (b) The carbonic acid exchange theory

**Donnan equilibrium** : This mechanism, given by F.G. Donnan (1927), takes into account the effect of non-diffusible ions, which may be present on one side of the membrane. Unlike diffusible ions, the membrane is not permeable to non-diffusible ions. Such ions are termed as fixed ions. They may be anions or cations. In a system, in which there are no fixed ions, there are equal number of anions and cations on both sides of the membrane at equilibrium. But in Donnan equilibrium, in order to balance the charge of the fixed ions (say anions), more ions of the other charge (say cations) would be required.

Mathematically, the Donnan equilibrium may be represented by following equation :

$$[C_i^+][A_o^-] = [C_o^+][A_i^-]$$

Here :  $C_i^+$  = Cations inside;  $C_o^+$  = Cations outside

$A_i^-$  = Anions inside;  $A_o^-$  = Anions outside

$$\frac{\text{Positive ions inside}}{\text{Positive ions outside}} = \frac{\text{Negative ions outside}}{\text{Negative ions inside}}$$

(2) **Active absorption** : Generally, the lipid-protein membrane of a cell is largely permeable to free ions. The energy is considered to be involved in the transport of such free ions across the membrane. The absorption of ions, involving use of metabolic energy, is called active absorption. Energy used in these mechanisms comes from metabolic activities, especially respiration. Mineral absorption is mainly active process. Hoagland (1944) indicated active ion absorption and their (ions) accumulation against concentration gradient in green algae *Nitella* and *Valonia*.

Following evidences show the involvement of metabolic energy in the absorption of mineral salts :

- (i) Higher rate of respiration increases the salt accumulation inside the cell.
- (ii) Respiratory inhibitors check the process of salt uptake.
- (iii) By decreasing oxygen content in the medium, the salt absorption is also decreased.

Active transport is necessary for living cells because certain substances must be concentrated and others must be excluded. Active uptake of minerals by roots mainly depends on availability of oxygen. Some of these are discussed below :

**Carrier concept** : This concept was proposed by Van den Honert (1937). The space in a cell or tissue where mineral ions enter by the usage of metabolic energy is called inner space. According to this concept there are separate carriers for cations and anions. A carrier forms an ion-carrier complex on the outer surface of the membrane. This complex breaks up and releases the ion into the inner space and this release is perhaps mediated by the enzyme *phosphatase*. The inactivated carrier is again activated by the enzyme *kinase* and in this process an ATP is used up. ATP molecule combine with carrier molecules and allow passage of substances against concentration gradient. The activated carrier again accepts new ions and the entire cycle is repeated.

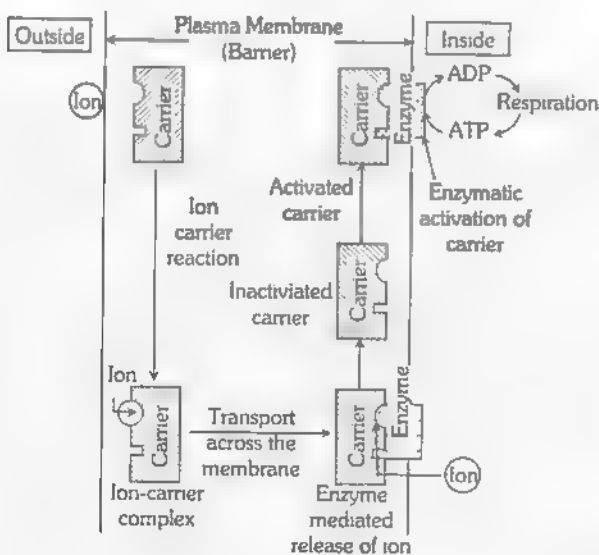


Fig : 4.2-2 The ion-carrier hypothesis

**Cytochrome – pump hypothesis** : This theory was proposed by Lundegardh (1950, 1954). According to this explanation only anions are absorbed actively, i.e., anion uptake requires energy and the absorption of cations does not require energy, (i.e., they are absorbed passively). At the outer surface of the membrane, the cytochrome undergoes oxidation and loses one electron and in exchange picks up an anion. This is then transported to the inner side of the membrane through to the cytochrome chain and on the inner surface of the membrane the anion is released and the cytochrome gets reduced by the action of dehydrogenase involved in respiration.

The cations move passively along the electrical gradient created by the accumulation of anions at the inner surface of the membrane.

The evidence in favour of Lundegardh's hypothesis is that the respiration increases when a plant is transferred from water to salt solution. The increased respiration is called salt respiration or anion respiration.

#### Criticism

- (i) It is applicable to absorption of anions only.
- (ii) It fails to explain selective absorption of ions.
- (iii) It has been observed that even cations can stimulate respiration.
- (iv) ETS is poorly developed in anaerobically respiring forms.

#### Protein-lecithin carrier concept : Bennet-Clark (1956)

proposed that the carrier could be some amphoteric molecule which can carry anions as well as cations. He suggested it to be a membrane-bound protein which is conjugated with a phosphatide called as lecithin. Lecithin functions as a carrier. According to this theory, the phosphate group in the phosphatide acts as the cation binding site and choline acts as the anion binding site. During transport, ions are picked up by lecithin to form an ion-lecithin-complex. The ions are released on the inner surface of the membrane due to hydrolysis of lecithin by the enzyme *lecithinase* into phosphatidic acid and choline.

Lecithin is resynthesised from these components in the presence of enzyme *choline acetylase* and *choline esterase* which requires ATP.

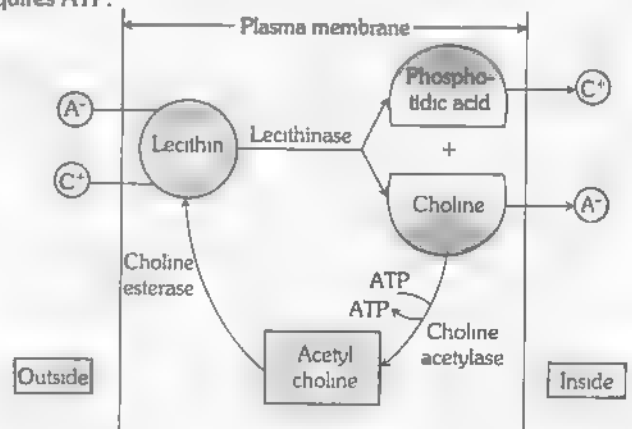


Fig : 4.2-3 The protein-lecithin carrier concept

Goldacre, 1952 proposed a mechanism of ion transport where contractile proteins act as ion carrier. They bind ions in unfolded condition on the outer face of the membrane and then contract releasing the ion into the cell and again become unfolded. The energy for this folding and unfolding is provided by ATP.

In hydrophytic plants, water and salts are absorbed by outer layer of plants.

### Factors affecting mineral absorption

The process of mineral absorption is influenced by the following factors :

**Temperature :** The rate of absorption of salts and minerals is directly proportional to temperature.

The absorption of mineral ions is inhibited when the temperature has reached its maximum limit, perhaps due to denaturation of enzymes.

**Light :** When there is sufficient light, more photosynthesis occurs. As a result more food energy becomes available and salt uptake increases.

**Oxygen :** A deficiency of  $O_2$  always causes a corresponding decrease in the rate of mineral absorption. It is probably due to unavailability of ATP. The increased oxygen tension helps in increased uptake of salts.

**pH :** It affects the rate of mineral absorption by regulating the availability of ions in the medium. At normal physiological pH monovalent ions are absorbed more rapidly whereas alkaline pH favours the absorption of bivalent and trivalent ions.

**Interaction with other minerals :** The absorption of one type of ions is affected by other type. The absorption of  $K^+$  is affected by  $Ca^{++}$ ,  $Mg^{++}$  and other polyvalent ions. It is probably due to competition for binding sites on the carrier. However, the uptake of  $K^+$  and  $Br^-$  becomes possible in presence of  $Ca^{++}$  ions. There is mutual competition in the absorption of  $K$ ,  $Rb$  and  $Cs$  ions.

**Growth :** Due to proper development surface area, no. of cells and no. of binding sites for mineral ions are increased. From that mineral absorption is also increased.

### Mineral translocation

P.R. Stout and D.R. Hoagland (1939) proved that mineral salts are translocated through xylem. After absorption of minerals by root, ions are able to reach xylem by two pathways.

(1) **Apoplast pathway :** In this pathway inflow of water takes place from the cell to cell through spaces between cell wall polysaccharides. Ions thus are able to move from cell wall of epidermis to cell walls of various cells in cortex, cytoplasm of endodermis, cell wall of pericycle and finally into xylem.

(2) **Symplast pathway :** In this pathway ions move through cytoplasm of epidermis and finally move through cytoplasm of cortex, endodermis, pericycle through plasmodesmata and finally into xylem.

Minerals in xylem are carried along with water to other parts of the plant along transpiration stream. Minerals reaching leaves take part in assimilation of organic compounds and then transported to other parts of the plant through phloem

### Nitrogen nutrition in plants

Higher plants generally utilize the oxidized forms such as nitrate ( $NO_3^-$ ) and nitrite ( $NO_2^-$ ) or the reduced form ( $NH_4^+$ ) of nitrogen which is made available by a variety of nitrogen fixers. Nitrogen can be fixed by three methods :

#### Process of Nitrogen fixation

On the basis of agency through which the nitrogen is fixed the process is divided into two types abiological and biological.

(1) **Abiological :** They are two types :

(i) **Natural or Atmospheric nitrogen fixation :** By photochemical and electrochemical reactions, oxygen combines with nitrogen to form oxides of nitrogen. Now they get dissolved in water and combine with other salts to produce nitrates.

Physical nitrogen fixation out of total nitrogen fixed by natural agencies approximately 10% of this occurs due to physical processes such as lightening (i.e., electric discharge), thunder storms and atmospheric pollution.

Due to lightening and thundering of clouds,  $N_2$  and  $O_2$  of the air react to form nitric oxide ( $NO$ ). The nitric oxide is further oxidised with the help of  $O_2$  to form nitrogen dioxide ( $NO_2$ ).



$NO_2$  combines with  $H_2O$  to form nitrous acid ( $HNO_2$ ) and nitric acid ( $HNO_3$ ). The acid falls along with rain water. Now it acts with alkaline radicals to form water soluble  $NO_3^-$  (nitrates) and  $NO_2^-$  (nitrites).



The nitrates are soluble in water and are directly absorbed by the plants.

(ii) **Industrial nitrogen fixation :** Nitrogen and hydrogen combines to form ammonia industrially, under pressure and temperature.

(2) **Biological nitrogen fixation :** The conversion of atmospheric nitrogen into inorganic or organic usable forms through the agency of living organisms is called biological nitrogen fixation. The process is carried by two main types of microorganisms, those which are "free living" or symbiotic and those which live in close symbiotic association with other plants.

(i) **Asymbiotic biological nitrogen fixation :** This is done by many aerobic and anaerobic bacteria, cyanobacteria (blue green algae) and some fungi e.g. :

**Free living bacteria :** Free living  $N_2$  fixing bacteria add 10–25 kg of nitrogen /ha/annum.

Aerobic	–	<i>Azotobacter</i>
Anerobic	–	<i>Clostridium</i>
Photosynthetic	–	<i>Chlorobium</i>
Chemosynthetic	–	<i>Thiobacillus</i>

**Cyanobacteria** (blue-green algae) e.g., *Anabaena*, *Nostoc*, *Tolypothrix cylindrospermum*, *Calothrix* and *Aulosira* etc. They add 20–30 kg of  $N_2$  per hectare of soil and water bodies.

**Free living fungi** e.g., Yeast cells and *Pullularia*.

(ii) **Symbiotic biological nitrogen fixation :** Symbiotic bacteria are found in the root nodules of the members of family Leguminosae. The best known nitrogen fixing symbiotic bacterium is *Rhizobium leguminosarum* (*Bacillus radicicola*).

*Rhizobium* penetrates to the cortex of root through infection thread. Simultaneously cortical cells or root are stimulated to divide more vigorously to form nodules on the root. Neither bacterium nor plant alone can fix nitrogen in such cases. Nitrogen fixation is actually the outcome of symbiotic relationship between the two. When a section of root nodules is observed the presence of a pigment, leghaemoglobin is seen to impart pinkish colour to it. This pigment is closely related to haemoglobin and helpful in creating optimal condition for nitrogen fixation. Like haemoglobin, leghaemoglobin is an oxygen scavenger. Fixation of nitrogen is done with the help of enzyme nitrogenase, which functions under anaerobic conditions. Leghaemoglobin combines with oxygen and protects nitrogenase.

Symbiotic bacteria (*Frankia*) have also been found to occur in root nodules of non-leguminous plants e.g., *Casuarina*, *Cycas*, *Alnus*, etc. Leaf nodules develop in some members of family Rubiaceae, the bacteria being *Mycobacterium*. Some cyanobacteria also have symbiotic association with plants e.g., Lichens; *Anthoceros* (a liverwort) and *Azolla* (a water fern).

**Mechanism of biological nitrogen fixation :** Several schemes incorporating such idea have been proposed and Burris (1966) accepts that the total reduction of nitrogen occurs on an enzyme complex (Nitrogenase) without release of intermediates less reduced than ammonia.

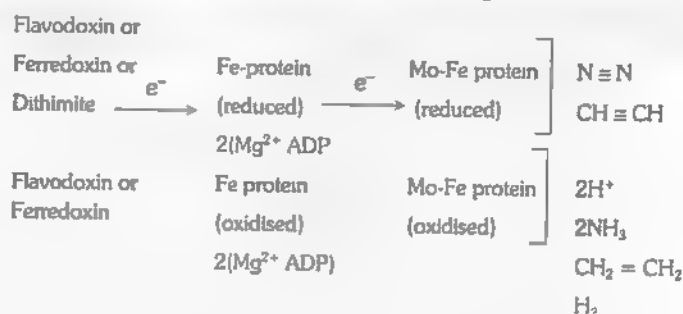
The enzyme complex nitrogenase consists of two sub-units

(i) A non-heme iron protein commonly called *Fe* protein (or dinitrogen reductase, component I)

(ii) An iron molybdenum protein called *MoFe* protein (or dinitrogenase, component II).

According to Burris (1966) hypothesis for nitrogen fixation suggesting the function of ATP and ferredoxin at each step in the reduction of nitrogen. The pretty function of ATP donor is furnished by pyruvate which also acts as electron donor for  $N_2$  reduction as well.

Pyruvate on one hand acts as ATP donor while on other hand it supplies hydrogen ions and electrons for nitrogen reduction via  $NADH_2$  and ferredoxin. The nitrogenase enzyme require 16 ATP molecules, 8 hydrogen ions and 8 electrons to reduce one molecule of nitrogen to  $2NH_3$  molecules.



Explaining the mechanism of nitrogenase activity, its now believed that electrons are transferred from the reducing agent (Ferredoxin, Flavoprotein or Dithionite) to complex of  $Mg$ -ATP and Fe-protein (component I). From here electrons flow to Mo-Fe protein (component II) and then to substrate (nitrogen) which is finally reduced (to  $NH_3$ ).

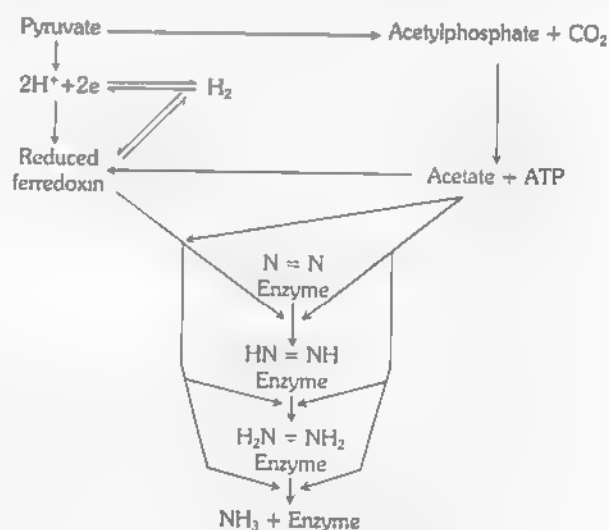


Fig : 4.2-4 Scheme suggesting the role of ATP and ferredoxin at each step in the reduction of nitrogen. Enzymes is nitrogenase (Burris, 1966)

The ammonia formed in biological nitrogen fixation is not liberated. It is highly toxic and is immediately converted into amino acids



The amino acids are transported through phloem to other parts of the plant.

#### Ammonification and nitrification

The free living nonsymbiotic nitrogen fixing organisms do not enrich the soil immediately. It is only after organism death that the fixed nitrogen enters the cyclic pool by the two steps namely the ammonification and nitrification.

**Ammonification :** The nitrogenous organic compounds in the dead bodies of plants and animals are converted into ammonia or ammonium ions in the soil. This is carried out by ammonifying bacteria. Ammonia is toxic to the plants but ammonium ions can be safely absorbed by the higher plants.

**Nitrification** : Once ammonia has been produced it is converted into nitrates by nitrifying activities and process is called nitrification. Soil bacteria such as *Nitrosomonas* and *Nitrosococcus* convert ammonia into nitrite ( $\text{NO}_2^-$ ) ions.



Nitrites are then oxidised to nitrates by *Nitrobacter*.



The nitrifying bacteria are chemoautotrophs and are benefited by utilising energy released in oxidation, which is used in chemosynthesis. At soil temperatures  $30^\circ\text{C} - 35^\circ\text{C}$  in alkaline soils and with sufficient moisture and aeration, the activity of ammonifying and nitrifying bacteria is found to be maximum.

Some bacteria such as *Thiobacillus denitrificans* and *Micrococcus denitrificans* also occur in the soil which convert the nitrate and ammonia into atmospheric free elemental nitrogen. Such bacteria are called denitrifying bacteria and the process is called denitrification. These bacteria act very well in soil where there is more water and less oxygen and there are high level of the carbohydrate.

#### Nitrate assimilation in plants

It is first reduced to ammonia and then incorporated into organic compounds.

The process of nitrate reduction to ammonia occurs in the following steps :

Nitrate  $\rightarrow$  Nitrite  $\rightarrow$  Hyponitrite  $\rightarrow$  Hydroxylamine  $\rightarrow$  Ammonia

(1) **Reduction of nitrate to nitrites** : First the nitrate is reduced to nitrite by an enzyme called nitrate reductase. The reductase enzyme is a flavoprotein and contains FAD (Flavin adenine dinucleotide) as prosthetic group which receives hydrogen from reduced NADP or NAD. Molybdenum in enzyme serves as electron carrier.

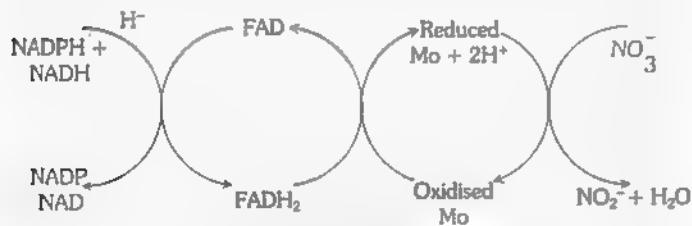


Fig : 4.2-5 Steps for nitrate reduction

(2) **Reduction of nitrites** : The nitrite ions are reduced to ammonia by an enzyme called nitrite reductase. This change occurs in leaves in the presence of light more rapidly and in dark with lesser speed. This is due to the reducing power of reaction from photochemical splitting of water.



Nitrite reductase does not need molybdenum but may require the presence of iron and copper. NADH and NADPH act as hydrogen donors.

**Application of fertilizers** : Most of the soil usually contain sufficient amounts of essential mineral elements for the better crop production. Some of them are, however, deficient in certain elements. These elements are required to be supplemented externally by adding the appropriate fertilizers. Moreover, constant agricultural cultivation in field may also cause depletion of certain elements which must be replenished in order to improve the fertility of soil. The important elements need to be replenished in crop fields are nitrogen, phosphorus and potassium. These are grouped as nitrogenous fertilizers, phosphate fertilizers and potash fertilizers. These are abbreviated as NPK. Common sources of NPK are ammonium chloride, ammonium sulphate, ammonium nitrate, bone meal, calcium magnesium phosphate and nitrate of soda.

#### Special modes of nutrition

The method of taking in and synthesis of various types of foods by different plants and animals is called nutrition.

Generally plants are autotrophic in their mode of nutrition, but there are some examples which are heterotrophic in their mode of nutrition. These plants are unable to manufacture their own food due to lack of chlorophyll or some other reasons.

(1) **Parasites** : These plants obtain either their organic food prepared by other organisms or depend upon other plants only for water and minerals with the help of which they can synthesize their own food. The living organism from which the parasite obtains its organic food or water and minerals is called host. Any part of the body of parasite is modified into a special organ called haustorium which enters into the cells of host and absorbs food or water and minerals from the host

Parasites can be classified into two categories :

(i) Total parasites. (ii) Semiparasites or partial parasites.

(i) **Total parasites** : These plants never possess chlorophyll, hence they always obtain their food from the host. They may be attached to branches, stem (stem parasites) or roots (root parasites) of the host plants.

**Total stem parasite** : *Cuscuta* is a rootless, yellow coloured, slender stem with small scale leaves, which twines around the host. The parasite develops haustoria (Small adventitious sucking roots) which enter the host plant forming contact with xylem and phloem of the host. It absorbs prepared food, water and minerals from the host plant.

**Total root parasite** : Total root parasites are common in the families like *Orobanchaceae*, *Rafflesiaceae*, *Balanophoraceae*, etc. *Orobanche*, *Rafflesia* and *Balanophora* are some of the common root parasites.

*Orobanche* is commonly known as broom rape. It has scale leaves and pinkish or bluish flowers. The tip of the root of parasite makes haustorial contact with the root of host and absorbs food from the host. *Orobanche* is usually parasitic upon brinjal, tobacco. In *Rafflesia* (stinking corpse lily) another root parasite, vegetative parts of the plant are highly reduced and represented by cellular filaments resembling fungal mycelium. These filaments get embedded in the soft tissue of the host while the flowers emerge out in the forms of buds

*Balanophora* occurs as a total root parasite in the roots of forest trees.

(ii) **Semiparasite or partial parasite** : Such parasitic plants have chlorophyll and, therefore, synthesize their organic food themselves. But they fulfil their mineral and water requirements from their host plants. These are of two types :

**Partial stem parasites** : The well known example of partial stem parasite is *Viscum album* (mistletoe) which parasitizes a number of shrubs and trees. The mature plant of *Viscum* is dichotomously branched with green leaves born in pairs attached on each node of stem. The shoots are attached to the host by means of haustoria. The primary haustoria reaches upto cortex of the host which runs longitudinally. It sends secondary haustoria which make connection with the xylem of the host and absorb water and minerals, *Loranthus* is another partial stem parasite.

**Partial root parasites** : The common example of partial (semi-parasite) root parasite is *Santalum album* (Sandal wood tree) which is an evergreen partial root parasite which grows in South India. It grows on the roots of *Dalbergia sisso*, *Eucalyptus*. Like other partial parasites, it also has green leaves and absorbs only minerals and water from the host plants.

Similarly, *Striga* on roots of sugarcane and *Thesium* on the roots of grasses are other partial root parasites.

(2) **Saprophyte** : These plants live upon dead organic matter and are responsible for conversion of complex organic substances into simple inorganic substances (minerals), e.g., some bacteria, some fungi (Yeast, *Mucors*, *Penicillium*, *Agaricus*), few algae (*Polytoma*), few bryophytes (*Buxbaumia*, *Hypnum* and *Splachnum*), few pteridophytes (like *Botrychium*) and some angiosperms (*Monotropa* and *Neottia*) also.

*Monotropa*, commonly known as Indian pipe, lacks chlorophyll and is colourless or ivory white. It is found in Khasi hills and in the dense forests of Shimla. *Monotropa*, though usually referred to as a saprophyte, actually gets its nourishment from fungal mycelium which surround its roots. Such association between roots of higher plants and fungi is known as mycorrhiza. *Neottia* (Bird's nest orchid) grows in the humus rich soil of the forests. It has very few reduced leaves and thick pale yellow stem. The roots lack root hairs and the nutrients are absorbed by mycorrhiza.

(3) **Symbiotic plant** : Sometimes two different species of organisms spend much or all of their lives in close physical association, deriving mutual benefit. Such an association is known as symbiosis and each organism is known as symbiont. Symbiotic association is so close that symbionts appear to be different parts of the same plant.

Symbiotic association may be between two higher plants or between a higher plant and a lower plant. Some common examples of symbiosis are described below.

**Lichens** : Lichens is a special group of plants, when an alga and fungus live together and are mutually benefitted (alga provides food and fungus provides water minerals and protection of alga).

The fungus component of the lichens, called mycobiont, is generally a member of Ascomycetae or occasionally a Basidiomycetae. The algal component of the lichen is known as phycobiont and is generally a member of Chlorophyceae (e.g., *Trebouxia*) or Cyanophyceae (e.g., *Nostoc*, *Gloeocapsa*).

**Mycorrhiza** : It is a mutually beneficial association between a fungus and the root of higher plant. In such association the fungal mycelium forms a mantle over the root surface and some of the hyphae penetrate between cortical cells and metabolites are transferred in both directions (i.e., from fungus to the root cells and vice-versa).

**Root nodules of leguminosae** : Members of the sub-family Papilionaceae of the Leguminosae (e.g., pea, beans, trifolium) harbour species of *Rhizobium*, a nitrogen fixing bacteria. The bacteria form nodules in the roots. They fix elemental nitrogen of the atmosphere and make it available to the plant in forms that can be utilized. In turn they derive food and shelter from the leguminous plant.

**Myrmecophily** : It is the symbiotic relationship between ants and some higher plants. The ants obtain food and shelter from the plant. They protect the plant (e.g., Mango) from other animals. In *Acacia sphaerocephala* the stipules are hollowed to function as ant shelter. Leaflet tips (Belt's corpuscles) and rachis (extrafloral nectaries) possess feeding materials. A higher plant which is benefitted by association with ants is called myrmecophyte. The term myrmecophily is also used for pollination by ants.

(4) **Carnivorous or Insectivorous plants** : These plants are autotrophic in their mode of nutrition but they grow in marshy or muddy soils, which are generally deficient in nitrogen and in order to fulfil their nitrogen requirement, these plants catch small insects. The organs and specially leaves of these plants are modified variously to catch the insects. These plants have glands secreting proteolytic enzymes which breakdown complex proteins into simple nitrogenous substances, which in turn are absorbed by these plants. Some of these plants are as follows :

**Drosera (Sundew)** : It is a herbaceous plant having spatulate or lunate leaves. The leaves are covered by glandular hair with a swollen tip. The glands secrete a sticky purple juice which shines like a dew drop in bright light sunshine, hence the name sundew. These long special hair are generally referred to as 'tentacles'. When an insect alights on the leaf, the tentacles curve due to thigmonasty. The insect is killed and its proteins are digested by pepsin hydrochloride. Similar tentacles are also found in *Drasophyllum*.

**Utricularia (Bladderwort)** : It is submerged floating aquatic herb which lacks roots. Some of the species of *Utricularia* also occur in moist soil. The leaves are dissected into fine segments and appear like roots. Some of the leaf segments are modified into pear-shaped sacs called bladders or utricles.

The bladders are triangular or semicircular structures having a single opening guarded by a valve. There are numerous bristles near the mouth and digestive glands inside. The bladders show special trap mechanism. The valve of the bladder opens on the inner side. When small aquatic animalcules enter the bladder along with water current, they get trapped inside. Their proteins are digested enzymatically. When a bladder is full of undigested matter, it degenerates.



**Nepenthes (Pitcher plant) :** They are commonly found in tropical areas like Assam and Meghalaya (i.e., *N. khasiana*). It is an endangered species. In this plant the leaf base is winged, petiole is tendrillar and the lamina is modified into pitcher. The pitcher has a distinct collar at the mouth and the apex is modified into the lid. The undersurface of the lid has alluring glands whereas the inner surface of pitcher is lined by numerous digestive glands and several downward directed hair. The lid attracts insects which slide down into the pitcher. The downward directed hair check their escape. The insect is killed and its proteins are digested by pepsin hydrochloride. Other insectivorous plants having leaf pitchers are *Sarracenia*, *Cephalotus*, *Heliamphora*, etc.

**Dionaea (Venus fly trap) :** It is a small herbaceous plant found mainly in America. The plant has a rosette of radiating leaves. The petiole is winged and photosynthetic. The lamina is bilobed and the midrib acts like a hinge between the two lobes of the lamina. Each lobe has 15-20 trigger hairs or bristles. These hairs are very sensitive to nitrogenous substances. When an insect alights on the leaf and touches the sensitive hairs, the two lobes of lamina fold along the midrib. Thus the insect is trapped in between the lobes. Pepsin hydrochloride secreted by the digestive glands, present in the upper part of the lobes digests the insect.

**Sarracenia (Pitcher plant; Devil's boot) :** This pitcher plant is found in the temperate regions. It has a very reduced stem which bears a rosette of leaves. The leaves are modified into pitchers. It can easily be distinguished from *Nepenthes* on the basis of its trumpet-shaped sessile pitchers. The pitchers of *Sarracenia* lack digestive enzymes and here the insects are decomposed by bacteria.

**Pinguicula (Butterwort) :** It is a herbaceous plant having a basal rosette of ovate leaves. The leaf margins are slightly curved in upward direction. The dorsal (upper) surface of leaf has two types of glands stalked and sessile. The stalked glands secrete mucilage while the sessile glands secrete digestive enzymes.

**Aldrovanda (Water flea trap) :** It is also a rootless, submerged aquatic plant (bog plant) recalling the habit of *Utricularia*. The leaves are bilobed with long petioles. There are five bristle like outgrowths associated with the lamina. The leaf surface is covered by viscid stalked glands. The proteins of the insect are digested enzymatically.

## Tips & Tricks

Woodward (1699) reported that plants grow better in muddy water as compared to fresh rain water.

De Saussure (1804) first of all demonstrated that plants obtain minerals from soil through root system.

Liebig for the first time discovered the presence of elements in plant ash.

**Tracer elements :** These are radioactive isotopes of elements, which are used to detect various metabolic pathways in plants, e.g.,  $C^{14}$ ,  $N^{15}$ ,  $P^{32}$ ,  $S^{35}$ , etc.).

Hydroponics developed by Geriche.

Venedium (V) is required by alga *Scenedesmus*.

Selenium (Se) is required by *Atriplex* and *Astragalus*.

Iodine is required by marine alga *Polysiphonia*.

The elements taken in the form of gas by prokaryotes only is nitrogen.

Critical elements are the elements in which soil is generally deficient e.g., N, P and K. These are given in form of fertilizers.

Silica : Found in grasses and diatoms.

Sodium : Found in halophytes.

Cobalt : Found in ferns (e.g., *Lycopodium*) taking part in growth.

Nickel : Enzyme urease uses it to hydrolyse urea by living organisms.

*Dischidia* is the pitcher plant, which is without lid and it is used only for storing rain water.

Haber-Bosch method is considered to be the best chemical method of fixing atmospheric nitrogen.

In *Rhizobium* cobalt play an important role in nitrogen fixation and is an essential constituents of vitamin  $B_{12}$ . It is used in 'cancer therapy'.

Cytozyme is a water soluble commercial preparation which contains essential mineral element for use as foliar spray.

The symptoms produced by the deficiency of mineral substances are called 'hunger sign'.

Cytochromes act as anion carriers.

Phytotron is the place or laboratory where plants can be maintained and studied under wide range of controlled conditions.

Winogradsky (1891). Discovered biological nitrogen fixation.

*Rafflesia* (largest flower in the world) was discovered by Sir Stamford Raffles from Java. Flower measures about a meter in diameter, about 11 kg in weight, smell is like rotten fish, pollination by elephants and found on roots of *Vitis* and *Cissus*.

*Sapria himalayensis* (largest flower in India), measures 15 cm – 30 cm in diameter.

*Cephalotus* (Fly Catcher). A deep rooted carnivorous herb with a rosette of pitchers for trapping small animals.

*Cuscuta*/Amarbel/Akashbel/Dodder : A dicot with no cotyledon (some workers consider it to have a single cotyledon). It is a total stem parasite but initially grows on soil.

Bird of paradise flower is *Sterilia reginae*.

Certain plants require very high doses of nitrogen. They are called heavy feeders, e.g., Zea mays.

*Arceuthobium* is the smallest dic of angiospermic parasite. It is total parasite that grows on a number of forest trees including *Pinus* and *Juniper*.

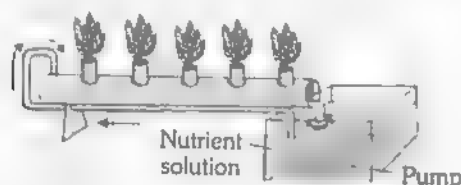


# **Ordinary Thinking**

## **Objective Questions**

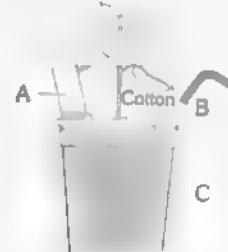
### **General**

- Which one of the following is not an essential mineral element for plants while the remaining three are  
[NCERT; MP PMT 1992; CBSE PMT (Maine) 2011]  
(a) Cadmium (b) Phosphorus  
(c) Iron (d) Manganese
- In plant nutrition elements are classified as major or minor depending on  
(a) Their availability in the soil  
(b) Their relative production in the ash obtained after burning the plants  
(c) The relative amounts required by the plants  
(d) Their relative importance in plant growth
- The given figure shows hydroponic / soil less plant production. Plants are grown in a tube or through placed on a slight incline. The arrows indicate the direction of flow of nutrient solution.  
Nutrient solution is sent to the elevated end of the tube from the reservoir by \_\_\_\_\_ and it flows back into reservoir due to \_\_\_\_\_  
[NCERT]



- (a) Pump, Gravity (b) Gravity, Pump  
(c) Gravity, Gravity (d) Pump, Pump
- Inorganic nutrients are present in the soil in the form of  
[MP PMT 1999; BHU 2008]  
(a) Molecules (b) Atoms  
(c) Electrically charged ions (d) Parasite
- Sulphur is an important nutrient for optimum growth and productivity in  
[CBSE PMT 2006]  
(a) Fibre crops (b) Oilseed crops  
(c) Pulse crops (d) Cereals
- An essential element is one  
[NCERT]  
(a) Improve plant growth  
(b) Present in plant ash  
(c) Is indispensable for growth and is irreplaceable  
(d) Available in soil
- Hydroponics are  
[NCERT; MP PMT 1992; KCET 1994; EAMCET 1995; CPMT 1998; Pb. PMT 1999; KCET 1999; AMU (Med.) 2005]  
(a) Growing of aquatic plants  
(b) Growing of floating aquatic plants  
(c) Growing of plants in sand  
(d) Growing of plants aqueous balanced nutrient

- Which of the following ions of heavy metals participate in process of photosynthesis in higher plants  
[AMU (Med.) 2005]  
(a) Pb, Fe, Ni, Co (b) Mg, Zn, Cu, Hg  
(c) Mg, Mn, Co, Fe (d) Mg, Cu, Mn, Fe
- Necrosis means  
(a) Yellow spots on the leaves  
(b) Death of tissue and decomposition  
(c) Darkening of green colour in leaves  
(d) None of the above
- Tracer elements are  
[MP PMT 2002]  
(a) Micro elements (b) Macro-elements  
(c) Radio isotopes (d) Vitamins
- Essential elements for plants are [MP PMT 2005; KCET 2007]  
(a) Life cycle incomplete without it  
(b) Non replaceable  
(c) Metabolism (necessary for it)  
(d) All above
- In hydrophytic plants, water and salts are absorbed by  
[MP PMT 1992]  
(a) Roots (b) Leaves  
(c) Stem (d) Outer layer of plants
- The given figure shows a typical setup for hydroponic technique. Choose the option which gives correct set of words for all the three blanks A, B and C  
[NCERT]



- (a) A - Funnel for adding water and nutrients, B - Aerating tube, C - Water  
(b) A - Funnel for adding nutrients only, B - Aerating tube, C - Nutrient solution  
(c) A - Funnel for adding water only, B - Aerating tube, C - Nutrient solution  
(d) A - Funnel for adding water and nutrients, B - Aerating tube, C - Nutrient solution
- The number of essential elements required for normal growth of plant is  
[BHU 2003]  
(a) 10 (b) 16  
(c) 20 (d) 25
- Aeroponic is also called as  
(a) Soilless cultivation of plants  
(b) Parthenocarpy  
(c) Vivipary  
(d) Phytotron
- Who gave the criteria of essentiality  
(a) R. Hill (b) F.F. Blackman  
(c) M.P. Kaushik (d) D.L. Arnon

17. Which one of the following scientists used the nutrient culture solution in hydroponic cultures [MP PMT 1995]  
(a) Sachs (b) Webster  
(c) Wallace (d) Knop
18. Which group of element is not essential for a normal plant [CBSE PMT 1996; AFMC 2009]  
(a) Potassium, calcium, magnesium  
(b) Iron, zinc, manganese, boron  
(c) Lead, nickel, iodine, sodium, barium  
(d) Magnesium, iron, molybdenum
19. The charcoal culture experiment is better than water culture experiment because  
(a) Plants get support  
(b) Problem of aeration is removed  
(c) Charcoal is an inert substance  
(d) All the above
20. Which of the following is not caused by deficiency of mineral nutrition [CBSE PMT 1997; MP PMT 2007]  
(a) Necrosis (b) Chlorosis  
(c) Etiolation (d) Shortening internode
21. Cultivation by sand culture is also called [MP PMT 1999]  
(a) Soilless cultivation (b) Green house effect  
(c) Photorespiration (d) None of these
7. Interveinal chlorosis of leaves is caused by the deficiency of [Kashmir MEE 1995]  
(a) Nitrogen (b) Calcium  
(c) Potassium (d) Magnesium
8. Chlorosis occurs when plants are grown in  
(a) Dark  
(b) Shade  
(c) Strong light  
(d) Fe free medium or (due to lack of iron or magnesium)
9. K, N, Ca, Mg deficiency causes [AFMC 2008; J & K CET 2010]  
(a) Chlorosis (b) Leaf curl  
(c) Exanthema (d) Little leaf
10. The possible resource of phosphorus ions and nitrogen ions in soil generally get depleted because they are usually found as [CBSE PMT 1994]  
(a) Positively charged ions  
(b) Negatively charged ions  
(c) A disproportionate mixture of negatively charged ions  
(d) Particles carrying no charge
11. Which of the following does NPK (Critical element) denote [NCERT]  
(a) Nitrogen, potassium, kinetin  
(b) Nitrogen, protein, kinetin  
(c) Nitrogen, protein, potassium  
(d) Nitrogen, phosphorus, potassium

### Macro-Nutrients

1. Which of the following is associated with electron transport in photosynthesis [MP PMT 2012]  
(a) Sodium (b) Potassium  
(c) Iron (d) Cobalt
2. Which element forms part of structure of chlorophyll molecule [MP PMT 1995; CBSE PMT 2003]  
(a) Fe (b) Mg  
(c) K (d) Mn
3. Deficiency symptoms of nitrogen and potassium are visible first in [CBSE PMT 2014]  
(a) Roots (b) Buds  
(c) Senescent leaves (d) Young leaves
4. In which of the following, all three are macronutrients [NEET (Phase-I) 2016]  
(a) Boron, zinc, manganese  
(b) Iron, copper, molybdenum  
(c) Molybdenum, magnesium, manganese  
(d) Nitrogen, carbon, phosphorus
5. Plants requiring two metallic compounds (minerals) for chlorophyll synthesis, are [NCERT; CPMT 1994; Odisha JEE 2008]  
Or  
One mineral activates the enzyme catalase and the other is a constituent of the ring structure of chlorophyll. These minerals are respectively [Kerala PMT 2012]  
(a) Fe and Ca (b) Fe and Mg  
(c) Cu and Ca (d) Ca and K
6. Which of the following is essential mineral element and is not a constituent of any enzyme but stimulate the activity of many enzymes [BHU 1994]  
(a) Zn (b) Mg  
(c) Mn (d) K
12. In nature, organic compounds invariably contain [MP PMT 1996]  
(a) Carbon (b) Phosphorus  
(c) Sulphur (d) Magnesium
13. Necrosis, or death of tissue particularly leaf tissue, is due to the deficiency of [NCERT; Kerala PMT 2010]  
(a) N, K, S (b) N, K, Mg and Fe  
(c) Mn, Zn and Mo (d) Ca, Mg, Cu and K  
(e) N, K, Mg, Fe, Mn, Zn and Mo
14. Which element is require for the germination of pollen grain [GUJCET 2007]  
Or  
Which of the following element is very essential for uptake and utilization of  $\text{Ca}^{2+}$  and membrane function [NCERT; Kerala PMT 2007]  
(a) Boron (b) Calcium  
(c) Chlorine (d) Potassium
15. The appearance of yellow edges to leaves is due to deficiency of this mineral element [Kerala PMT 2004]  
(a) Calcium (b) Magnesium  
(c) Potassium (d) Sulphur  
(e) Molybdenum
16. The most abundant element present in the plants is [CBSE PMT 2004; CPMT 2010]  
Or  
Which of the following is not absorbed through soil  
(a) Manganese (b) Iron  
(c) Carbon (d) Nitrogen

17. The major portion of the dry weight of plants comprises of  
[CBSE PMT 2003]
- Or
- Frame work elements in plants are
- (a) Carbon, hydrogen and oxygen  
(b) Nitrogen, Phosphorus and potassium  
(c) Calcium, magnesium and sulphur  
(d) Carbon, nitrogen and hydrogen
18. Those fertilizers, which provide all the essential elements such as *N, P* and *K* etc. required for plant growth, are called  
[BHU 2001]
- (a) Direct fertilizers (b) Indirect fertilizers  
(c) Complete fertilizers (d) Incomplete fertilizers
19. Which of the following element is used up in phosphorylation  
[AFMC 2000, 12]
- (a) Calcium and sulphur  
(b) Chlorine and manganese  
(c) Iron and phosphorous  
(d) Magnesium and phosphate
20. Which of the following is not an essential macro-element for the growth of plants  
[CPMT 1993, 96, 1999]
- (a) *N* (b) *Zn*  
(c) *Ca* (d) *K*
21. Most common free ion in a cell is
- (a) *P* (b) *K*  
(c) *Fe* (d) *B*
22. The major role of phosphorus in plant metabolism is  
[MP PMT 1994]
- (a) To generate metabolic energy  
(b) To evolve oxygen during photosynthesis  
(c) To evolve carbon dioxide during respiration  
(d) To create anaerobic conditions
23. In plants sulphur is found as
- (a) Fast moving (b) Moving  
(c) About non-moving (d) None of the above
24. Which one is not related with plant ash  
[MP PMT 1997]
- (a) Trace elements (b) Essential elements  
(c) Nitrogen (d) Mineral elements
25. Plants absorb phosphates as
- (a) Soluble phosphate (b) All phosphates  
(c) Phosphoric acid (d) As element
26. Which of the following is a macro nutrient  
[CPMT 1994]
- (a) *Ca* and *Mg* (b) *Mo*  
(c) *Mn* (d) *Zn*
27. Deficiency of which of the following element cause weakening of pedicel and petiole
- Or
- Which of the following is required for binding protein with nucleic acid
- (a) Magnesium (b) Zinc  
(c) Nitrogen (d) Calcium
28. Magnesium is mainly present in the form of
- (a) Citrate (b) Bicarbonate  
(c) Carbonate (d) Phosphate
29. The constant *pH* of body fluid is maintained by buffer salts like
- (a) Potassium phosphates  
(b) Sodium phosphates  
(c) Adenosine monophosphate  
(d) Sodium and potassium phosphates
30. Premature leaf fall is caused due to the deficiency of  
[AFMC 1997]
- (a) Molybdenum (b) Sulphur  
(c) Sodium (d) Phosphorus
31. Which of the following is considered to be the elements between macro-nutrients and micro-nutrients
- (a) Iron (b) Nitrogen  
(c) Phosphorus (d) Manganese
32. The cause of special flavour in onion and garlic is due to the presence of
- Or
- Yellowing of tea leaf takes place by the deficiency of
- (a) Sulphur (b) Phosphorus  
(c) Potassium (d) Nitrogen
33. Which is essential for root hair growth  
[BHU 2005]
- Or
- The mineral present in cell wall is  
[MP PMT 2007]
- (a) *Zn* (b) *Ca*  
(c) *Mo* (d) *S*
34. Rapid deterioration of root and shoot tip occurs due to the deficiency of  
[DPMT 2004]
- (a) Calcium (b) Phosphorus  
(c) Nitrogen (d) Carbon
35. About 98 percent of the mass of every living organism is composed of just six elements including carbon, hydrogen, nitrogen, oxygen and  
[CBSE PMT 2007]
- (a) Phosphorus and sulphur (b) Sulphur and magnesium  
(c) Magnesium and sodium (d) Calcium and phosphorus
36. Phosphorus is a structural element in  
[Pb. PMT 1999]
- (a) Fat (b) Starch  
(c) Nucleotide (d) Carbohydrate
37. Which of the following is not a macro-nutrient  
[CPMT 1994]
- Or
- Which is essential for the growth of root tip  
[NEET (Phase-II) 2016]
- (a) *Mn* (b) *Ca*  
(c) *Mg* (d) Phosphorus
38. Presence of phosphorus in a plant
- (a) Brings about healthy root growth  
(b) Retards fruit ripening  
(c) Retards protein formation  
(d) None of the above
39. Essential macroelements are  
[MP PMT 1993]
- (a) Absorbed from soil  
(b) Manufactured during photosynthesis  
(c) Produced by enzymes  
(d) Produced by growth hormones

## Micro-Nutrients

- A trace element is an element which [NCERT]
  - Is a radioactive and can be traced by Geiger counter
  - Is required in very minute amounts
  - Draws other element out of protoplasm
  - Was one of the first to be discovered in protoplasm
- Micro-nutrients are [CPMT 2002]
  - Less important in nutrition than macro-nutrients
  - As important in nutrition as macro-nutrients
  - May be omitted from culture media without any detrimental effect on the plant
  - Called micro because they play only minor role in nutrition
- Deficiency of molybdenum cause
  - Poor development of vasculature
  - Bending of leaf tip
  - Yellowing of leaves
  - Mottling and necrosis of leaves
- Find out the correctly matched pair [Kerala PMT 2012]
 

Nutrients	Functions
(a) Zinc	Helps to maintain the ribosome structure
(b) Magnesium	Needed during the formation of mitotic spindle
(c) Calcium	Plays a role in the opening and closing of stomata
(d) Manganese	Needed in the splitting of water to liberate oxygen during photosynthesis
(e) Potassium	Needed in the synthesis of auxin
- In a Citrus plantation, all the plants were found to be suffering from the die-back disease, spraying of fungicides was of no help. This problem was due to the deficiency of
  - Copper
  - Gibberellic acid
  - Zinc
  - Auxins
- Appearance of brown spots surrounded by chlorotic veins is a prominent toxicity symptom of [AMU (Med.) 2009]
  - Mn
  - Mo
  - Mg
  - Zn
- Which of the following is widely used metal cofactor [CBSE PMT 2003]
  - $\text{Ca}^{2+}$
  - $\text{Al}^{3+}$
  - $\text{Ni}^{2+}$
  - $\text{Mg}^{3+}$
- For its activity, carboxypeptidase requires [NCERT; CBSE PMT (Mains) 2012]
 

Or

Which one is the co-factor of carbonic anhydrase [WB JEE 2010]

  - Zinc
  - Iron
  - Niacin
  - Copper

- Apple fruit develop internal cork due to deficiency of

Or

'Pecole crack' is caused by the deficiency of

- Magnesium
  - Iron
  - Manganese
  - Boron
- Micronutrients are needed in amounts equivalent to [AMU (Med.) 2010]
    - 8m mole/kg of dry matter
    - 18m mole/kg of dry matter
    - 25m mole/kg of dry matter
    - 30m mole/kg of dry matter
  - Mottle leaf in citrus plants is due to deficiency of [MP PMT 1997]

Or

One of the causes of little leaf disease is due to deficiency of [J & K CET 2008]

- Boron
  - Magnesium
  - Zinc
  - None of these
- The deficiency of molybdenum induces
    - Citrus die back disease
    - Pea rosette disease
    - Cauliflower whip tail disease
    - White bud of maize
  - Boron in green plants assists in [CBSE PMT 2003]
    - Sugar transport
    - Activation of enzymes
    - Acting as enzyme cofactor
    - Photosynthesis
  - Study the following lists

List-I		List-II	
(A)	Photolysis of water	(I)	Zinc
(B)	Diazotrophy	(II)	Copper
(C)	Cytochrome 'c' oxidase	(III)	Manganese
(D)	Biosynthesis of IAA	(IV)	Molybdenum
		(V)	Boron

The correct match is [MP PMT 1992; EAMCET 2009]

- | A       | B  | C   | D  |
|---------|----|-----|----|
| (a) III | II | I   | V  |
| (b) III | IV | II  | I  |
| (c) V   | II | III | IV |
| (d) IV  | I  | III | II |
- The deficiencies of micronutrients, not only affects growth of plants but also vital functions such as photosynthetic and mitochondrial electron flow. Among the list given below, which group of three elements shall affect most, both photosynthetic and mitochondrial electron transport [NCERT; CBSE PMT 2005]
    - Cu, Mn, Fe
    - Co, Ni, Mo
    - Mn, Co, Ca
    - Ca, K, Na
  - The elements arsenic, copper and mercury have which of the following effect
    - Catalytic effect
    - pH effect
    - Toxic effect
    - Antagonistic action
  - Deficiency of iron causes [MP PMT 1995]
    - Bending of leaf tip
    - Interveneal chlorosis first on young leaves
    - Decrease of protein synthesis
    - Reduced leaves and stunted growth

18. Zn, Mo, Fe, Cu are [DPMT 2007]  
(a) Trace elements (b) Non-essential elements  
(c) Macro nutrients (d) None of these
19. Gray speck disease in oats takes place by the deficiency of [CBSE PMT 2003]  
(a) Zinc (b) Copper  
(c) Potassium (d) Manganese
20. Which of the following is not a micro or trace element for plant growth [MP PMT 1992, 2003; CBSE PMT 2007]  
(a) Boron (b) Molybdenum  
(c) Manganese (d) Calcium
21. Which one of the following is not a micronutrient [CBSE PMT (Pre.) 2010]  
(a) Boron (b) Molybdenum  
(c) Magnesium (d) Zinc
22. The micronutrient least required by plants is [DPMT 1992]  
(a) Calcium (b) Nickel  
(c) Manganese (d) Boron
23. The plants accept Zn as [CBSE PMT 2000]  
(a) Zn (b)  $Zn^{2+}$   
(c) ZnO (d)  $ZnSO_4$
24. Major role of minor essential elements is to act as [AIEEE Pharmacy 2004]  
(a) Co-factors of enzymes  
(b) Building blocks of important amino acids  
(c) Constituents of hormones  
(d) Binders of cell structure
25. Which one of the following elements plays an important role in biological nitrogen fixation [MP PMT 1992; CBSE PMT 1995, 2003; AFMC 2002; AIEEE Pharmacy 2004; DUMET 2009; CBSE PMT (Pre.) 2010]  
Or  
Browning of cauliflower takes place due to deficiency of which one of the following elements  
(a) Molybdenum (b) Manganese  
(c) Copper (d) Zinc
26. Which one of the following nutrient serves as micro elements for plant growth [MP PMT 1995; RPMT 1995; AMU (Med.) 2012]  
(a) Manganese, copper, calcium, zinc  
(b) Sodium, potassium, boron, chlorine  
(c) Sodium, nickel, chlorine, copper  
(d) Copper, molybdenum, zinc, nickel
27. Which of the following is micro-element in plant [CBSE PMT 1996; HP PMT 2005]  
(a) Manganese (b) Nitrogen  
(c) Magnesium (d) Calcium
28. Which of the following is the importance of molybdenum in plants metabolism [Pb. PMT 1999; BHU 2012]  
(a) Carbon assimilation  
(b) Nitrate reduction  
(c) Plant breeding  
(d) Chromosome contraction
29. Which of the following element is a component of ferredoxin  
(a) Cu (b) Mn  
(c) Zn (d) Fe

## Mineral absorption

1. Conduction of inorganic materials in plants occur mainly through or Minerals absorbed by roots move to the leaf through [Manipal 1995]  
(a) Xylem (b) Phloem  
(c) Sieve tube (d) None
2. Active transport from outside to inside of molecules across a membrane requires  
(a) Cyclic AMP (b) Acetyl chloride  
(c) ATP (d) Phloroglucinol
3. Ion uptake is called active because  
(a) Ions are active (b) Energy is expended  
(c) Ions move freely (d) Ions move passively
4. Plants absorb mineral salts from the soil solution through  
(a) A semipermeable membrane into the cytoplasm  
(b) Perforation at the apex of root hair cells  
(c) The cell wall which is semipermeable  
(d) None of these
5. The theory which suggest that the  $CO_2$  produced in respiration plays an important role in mineral absorption  
(a) Contact exchange theory  
(b) Carbonic acid exchange theory  
(c) Active absorption theory  
(d) None the above
6. All mineral salts are absorbed in cells as [RPMT 1991, 95]  
(a) Ions (b) Atoms  
(c) Molecules (d) All the above
7. Carrier proteins are involved in [MP PMT 1998; BVP 2003]  
(a) Active transport of ions (b) Passive transport of ions  
(c) Water transport (d) Water evaporation
8. Which statement is incorrect for ion-channels [WB JEE 2008]  
(a) They are proteins  
(b) Movement through them is simple diffusion  
(c) Movement through them is from high to low concentration  
(d) All ions pass through the same type of channel
9. Entry of mineral ions in plant root cells by diffusion is [CBSE PMT 1996]  
(a) Passive absorption (b) Active absorption  
(c) Osmosis (d) Endocytosis
10. Active uptake of minerals by roots mainly depends on the [AIEEE Pharmacy 2003]  
(a) Availability of oxygen  
(b) Light  
(c) Temperature  
(d) Availability of carbon dioxide
11. The plant ash is an indication of [CPMT 2004]  
(a) Organic matter of plant  
(b) Waste product  
(c) Mineral salts absorbed by plants  
(d) None of these

12. Minerals are absorbed by a plant from the soil by a process  
 (a) Independent of water absorption  
 (b) Dependent on water absorption  
 (c) Dependent on strength of solutions  
 (d) Dependent on osmosis
13. By which method ions are absorbed by plants [RPMT 1992]  
 (a) By difference in DPD  
 (b) By difference in water potential  
 (c) By carriers and pumps  
 (d) By molecular diffusion
14. Nobel prize of 1991 for discovering the single ion channels in cell was awarded to  
 (a) Waston and Hargobind Khorana  
 (b) Erwin Neher and Bert Stakmann  
 (c) Nirenberg and Kornberg  
 (d) Holley and Matthaei
15. In the light of carrier concept, the transport of ion across the membrane is  
 (a) Passive process (b) Non-osmotic process  
 (c) Osmotic process (d) Active process
16. If the amount of an ion absorbed by a root hair cell at  $0^{\circ}\text{C}$  is 5 gm and at  $20^{\circ}\text{C}$  is 20 gm. The amount of this ion absorbed actively should be  
 (a) 25 gm (b) 20 gm  
 (c) 15 gm (d) 5 gm
17. Solutes are absorbed by a plant cell through  
 (a) Osmosis (b) Diffusion  
 (c) Active absorption (d) Passive absorption

### Nitrogen nutrition

1. Most of the plants obtain or absorb nitrogen from soil in the form of [NCERT; Odisha PMT 2002; MP PMT 2005; AFMC 2010]  
 (a) Free nitrogen gas  
 (b) Nitric acid  
 (c) Nitrite  
 (d) Nitrates and ammonium salt
2. In root nodules of legumes, leg-haemoglobin is important because [NCERT; AMU (Med.) 2006; DUMET 2009]  
 (a) It transports oxygen to the root nodule  
 (b) It acts as an oxygen scavenger  
 (c) It provides energy to the nitrogen fixing bacterium  
 (d) It acts as a catalyst in trans-amination
3. The possibility of Increase of infectious disease become more due to more supply of  
 (a) Potassium (b) Magnesium  
 (c) Copper (d) Nitrogen
4. Cell elongation is adversely affected by

Or

Element required by plant in large quantity is [DPMT 1992]

- (a) Sodium (b) Cobalt  
 (c) Manganese (d) Nitrogen

5. The enzyme responsible for the reduction of molecular nitrogen to the level of ammonia in leguminous root nodule is [Kerala PMT 2009; AIIMS 2013]

Or

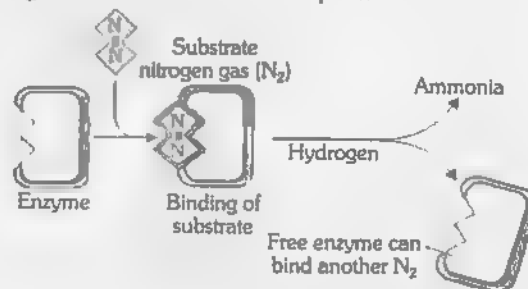
The enzyme responsible for atmospheric nitrogen fixation is [AIIMS 2000; CBSE PMT 2001]

- (a) Nitrogenase (b) Nitrate reductase  
 (c) Nitrite reductase (d) Hydrogenase  
 (e) Carboxylase
6. An important essential element is necessary in plants for protein synthesis

Or

The most important element associated with protoplasm and proteinaceous materials of plant is [MP PMT 2010]

- (a) Calcium (b) Phosphorus  
 (c) Magnesium (d) Nitrogen
7. The given figure represents the Nitrogen fixation. See the diagram and select the correct option



- I. Nitrogenase catalyses the reaction  
 II. The formation of ammonia is a reductive process  
 III. One molecule of nitrogen produces two molecules of ammonia  
 IV. Nitrate reductase catalyse the reaction  
 V. Formation of ammonia is an oxidative process  
 VI. One molecule of nitrogen produces one molecule of ammonia [NCERT]
- (a) III, IV and V are correct (b) I, V and VI are correct  
 (c) IV, V and VI are correct (d) I, II and III are correct
8. Nitrogen is an important constituent of [MP PMT 1994, 2002]  
 (a) Proteins (b) Lipids  
 (c) Carbohydrates (d) Polyphosphates
9. Which one of the following is an amide involved in nitrogen assimilation by plants [NCERT; Kerala PMT 2009]  
 (a) Glutamate (b) Alanine  
 (c) Asparagine (d) Serine  
 (e) Glycine
10.  $\text{N}_2 + 8\text{e}^- + 8\text{H}^+ + 16\text{ATP} \rightarrow 2\text{NH}_3 + \text{H}_2 + 16\text{ADP} + 16\text{P}_i$   
 The above equation refers to [NCERT; Kerala PMT 2007]  
 (a) Ammonification (b) Nitrification  
 (c) Nitrogen fixation (d) Denitrification  
 (e) Reductive amination
11. For its action, nitrogenase requires [NCERT; CBSE PMT (Mains) 2012]  
 (a) High input of energy (b) Light  
 (c)  $\text{Mn}^{2+}$  (d) Super oxygen radicals

12. Which one of the following can fix atmospheric nitrogen directly  
(a) Pea (b) *Brassica*  
(c) Castor (d) *Petunia*
13.  $N_2$  fixation is  
[CPMT 1996; MHCET 2003; Odisha JEE 2005]  
(a)  $N_2 \rightarrow NH_3$  (b)  $N_2 \rightarrow NO_3$   
(c)  $N_2 \rightarrow$  Amino acid (d) Both (a) and (b)
14. Nodules with nitrogen fixing bacteria are present in  
[AFMC 2001; CPMT 2003]  
(a) Cotton (b) Gram  
(c) Wheat (d) Mustard
15. Legume plants are important because they [CPMT 2002]  
(a) Help in  $NO_2$  fixation (b) Not help in  $NO_2$  fixation  
(c) Increased soil fertility (d) All of these
16. Knot like bodies known as 'nodules' found in the roots of groundnut plant are produced by [BHU 2003]  
(a) *Azospirillum* (b) *Azotobacter*  
(c) *Pseudomonas* (d) *Rhizobium*
17. The limiting factor in nitrification of soil is [CPMT 2010]  
(a) Soil nature (pH) (b) Light  
(c) Temperature (d) Air
18. Which of the following pigments is essential for nitrogen fixation by leguminous plants [HP PMT 2005; AIIMS 2012]  
(a) Anthocyanin (b) Phycocyanin  
(c) Phycoerythrin (d) Leghaemoglobin
19. Fertilizers have a formula written in a set of three figures 8 – 10 – 22. What for does it stand  
(a) % of Ca, Mg, P (b) % of N, S, P  
(c) % of N, P, K (d) % of Fe, Mg, K
20. The conversion of ammonia into nitrites and nitrates is called [MP PMT 1996; J & K CET 2005]  
(a) Ammonification (b) Nitrification  
(c) Denitrification (d) All of these
21. Nif genes occur in [MP PMT 1996; CPMT 2004]  
(a) *Rhizobium* (b) *Aspergillus*  
(c) *Penicillium* (d) *Streptococcus*
22. Nitrates are converted to nitrogen by [Pb. PMT 2004]  
(a) Nitrogen fixing bacteria (b) Ammonification bacteria  
(c) Denitrifying bacteria (d) Nitrifying bacteria
23. Symbiotic nitrogen fixation in non-leguminous plant is carried out by [BHU 1994; Odisha JEE 2005]  
(a) *Azotobacter* (b) *Brodyrhizobium*  
(c) *Clostridium* (d) *Frankia*
24. Leguminous plants are able to fix atmospheric nitrogen through the process of symbiotic nitrogen fixation. Which one of the following statements is not correct during this process of nitrogen fixation [CBSE PMT (Malina) 2010]  
(a) Leg haemoglobin scavenges oxygen and is pinkish in colour  
(b) Nodules act as sites for nitrogen fixation  
(c) The enzyme nitrogenase catalyses the conversion of atmospheric  $N_2$  to  $NH_3$   
(d) Nitrogenase is insensitive to oxygen
25. Higher plants obtain nitrogen from soil that has [MP PMT 2013]  
(a) Six forms ( $NO_3$ ,  $NO_2$ ,  $N_2O_2$ ,  $N_2$ ,  $NH_2OH$ ,  $NH_3$ ) of nitrogen with oxidation number ranging from +5 to -3  
(b) Six forms ( $NO_3$ ,  $NO_2$ ,  $N_2O_2$ ,  $N_2$ ,  $NH_2OH$ ,  $NH_3$ ) of nitrogen with oxidation number ranging from +6 to -3  
(c) Five forms ( $NO_3$ ,  $NO_2$ ,  $N_2$ ,  $NH_2OH$ ,  $NH_3$ ) of nitrogen with oxidation number ranging from +5 to -3  
(d) Five forms ( $NO_3$ ,  $NO_2$ ,  $N_2$ ,  $NH_2OH$ ,  $NH_3$ ) of nitrogen with oxidation number ranging from +6 to -3
26. The first stable product of fixation of atmospheric nitrogen in leguminous plants is [NEET 2013]  
(a) Glutamate (b)  $NO_2^-$   
(c) Ammonia (d)  $NO_3^-$
27. Which two distinct microbial processes are responsible for the release of fixed nitrogen as dinitrogen gas ( $N_2$ ) to the atmosphere [NEET (Karnataka) 2013]  
(a) Aerobic nitrate oxidation and nitrite reduction  
(b) Decomposition of organic nitrogen and conversion of dinitrogen to ammonium compounds  
(c) Enteric fermentation in cattle and nitrogen fixation by *Rhizobium* in root nodules of legumes  
(d) Anaerobic ammonium oxidation and denitrification

### Special modes of nutrition

1. A plant that manufactures its own food is  
(a) Autotroph (b) Parasite  
(c) Epiphyte (d) Saprophyte
2. Plants which are unable to manufacture their food wholly or partially are  
(a) Autophytes (b) Heterophytes  
(c) Halophytes (d) Holophytes
3. In *Nepenthes* (Pitcher plant), the pitcher is formed due to modification of [KCET 2004; Odisha JEE 2010]  
(a) Leaf petiole (b) Leaf lamina  
(c) Tendril (d) Leaflet
4. Epiphytes are the plants which are dependent on other plants [BHU 1996]  
(a) Only for water (b) For water and food  
(c) Only for food (d) Only for shelter (support)
5. Partial parasite is dependent upon the host for  
(a) Support (b) Food at times  
(c) Water (d) Water and minerals
6. *Cuscuta* is an example of [CPMT 1994, 2003; BVP 2000; CBSE PMT (Malina) 2012]  
(a) Ectoparasitism (b) Brood parasitism  
(c) Predation (d) Endoparasitism
7. *Viscum album* grows on trees. This is an example of [DPMT 2006]  
(a) Symbiosis (b) Parasitism  
(c) Commensalism (d) Predation

8. Biotrophic nutrition is shown by [CPMT 2010]  
(a) Humans (b) Saprophytic plants  
(c) Invertebrates (d) Insectivorous plants
9. Insectivorous plants usually grow in soils which are deficient in [BHU 1997, 2004; Pb. PMT 1999, 2001, 04; JIPMER 2000, 02; BVP 2001; Kerala CET 2002; AFMC 2003; Odisha JEE 2005; CPMT 2009]  
(a) Nitrogen (b) Water  
(c) Organic matter (d) Ca/Mg
10. *Viscum* and *loranthus* are [AFMC 2004]  
(a) Partial root parasite (b) Partial stem parasite  
(c) Total root parasite (d) Total stem parasite
11. *Drosera* catches insects by means of  
(a) Bladder (b) Pitcher  
(c) Tentacles secreting shining liquid  
(d) Adhesive disc
12. *Balanophora/Orobancha* is a [CPMT 1992; Bih. PMT 1994, 2002; BHU 1996]  
Or  
Biggest flower belongs to a plant which is [CBSE PMT 1999]  
(a) Total root parasite (b) Partial root parasite  
(c) Partial stem parasite (d) Total stem parasite
13. *Santalum album* is [DPMT 2002]  
(a) Partial root parasite (b) Partial stem parasite  
(c) Total stem parasite (d) Total root parasite
14. Select the one, which is pitcher plant [DPMT 1997; Chd. CET 1997]  
(a) *Drosera* (b) *Utricularia*  
(c) *Sarracenia* (d) *Aldrovanda*
15. Bird of Paradise flower is [JIPMER 2002]  
(a) *Ravenea madagascariensis*  
(b) *Sterilizia reginae*  
(c) *Heliconia schlideana*  
(d) *Musa chinensis*
16. Majority of the orchids are  
Or  
A plant growing on another plant without drawing any nourishment is  
(a) Epizoics (b) Epiphytes  
(c) Saprophytes (d) Parasites
17. Botanical name of Venus Fly trap is [JIPMER 2000; Chd. CET 2002]  
Or  
Insectivorous plant with rosette of spiny margined bilobed hinged and winged leaves for catching the prey is [CPMT 1992]  
(a) *Aldrovanda* (b) *Dionaea muscipula*  
(c) *Utricularia* (d) *Nepenthes*
18. One of the following is an insectivorous plant [AFMC 1996]  
(a) *Balanophora* (b) *Orobancha*  
(c) *Rafflesia* (d) *Drosera*
19. Which one is the largest root parasite [BHU 1996, 98; CPMT 1998; MP PMT 2009]  
(a) *Rafflesia* (b) *Monotropa*  
(c) *Arceuthobium* (d) All of these
20. *Nepenthes khasiana* is a/an [AIIMS 1999; MP PMT 2012]  
(a) Fungicidal and wet land plant  
(b) Insectivorous and endangered/endemic plant  
(c) Fungicidal and endangered plant  
(d) Insectivorous and wet land plant
21. Botanical generic name of bladderwort is [MP PMT 2010]  
Or  
A rootless aquatic in which a portion of leaf is modified to form a bladder for catching small aquatic animals is [CPMT 1998; DUMET 2009]  
(a) *Drosera* (b) *Nepenthes*  
(c) *Utricularia* (d) *Dionaea*
22. Plants obtaining food from other plants by means of haustoria are [CPMT 1995; AFMC 2002; J & K CET 2010]  
(a) Symbionts (b) Parasites  
(c) Hydrophytes (d) Saprophytes
23. Insects captured by carnivorous plants partially meet their requirement of [CPMT 1996; Odisha JEE 1997; Pb PMT 1997]  
(a) Organic matter (b) Enzymes  
(c) Water (d) Nitrogen
24. *Nepenthes* is [MP PMT 1995]  
(a) Both producer and primary carnivore  
(b) Producer  
(c) Consumer  
(d) None of these
25. *Rhizophora* is an example of [RPMT 1995]  
Or  
The plants that grow on saline soils with high concentration of NaCl, MgSO<sub>4</sub> and MgCl<sub>2</sub> are called [Kerala CET 2003]  
(a) Lithophyte (b) Fresh water aquatic  
(c) Mesophyte (d) Halophyte
26. A plant living symbiotically inside another plant is [AFMC 1994]  
(a) Saprophyte (b) Endophyte  
(c) Semiparasite (d) Parasite
27. Which is not an insectivorous plant [Chd. CET 1997]  
Or  
A pitcher plant without lid  
(a) *Dionaea* (b) *Dischidia*  
(c) *Drosera* (d) *Pinguicula*
28. A pair of insectivorous plants is [CBSE PMT 1999; Odisha JEE 2009]  
(a) *Drosera* and *Rafflesia*  
(b) *Nepenthes* and Bladderwort  
(c) *Dionaea* and *Viscum*  
(d) Venus fly trap and *Rafflesia*
29. Match the following with correct combination
- | Column I |                    | Column II |                     |
|----------|--------------------|-----------|---------------------|
| A.       | <i>Cuscuta</i>     | 1.        | Saprophyte          |
| B.       | <i>Eichornia</i>   | 2.        | Pneumatophore       |
| C.       | <i>Monotropa</i>   | 3.        | Insectivorous plant |
| D.       | <i>Rhizophora</i>  | 4.        | Parasite            |
| E.       | <i>Utricularia</i> | 5.        | Root pocket         |
- [BHU 1999; KCET 2001; HP PMT 2001; Kerala PMT 2002, 08]  
(a) A-4, B-3, C-1, D-5, E-2  
(b) A-4, B-5, C-1, D-2, E-3  
(c) A-2, B-3, C-1, D-5, E-4  
(d) A-3, B-1, C-5, D-4, E-2  
(e) A-2, B-5, C-4, D-3, E-1



30. Pitcher plant is

[KCET 1998]

Or

*Drosera* and *Sarracenia* are

- (a) Herbivorous (b) Carnivorous  
(c) Saprotroph (d) All of these

31. Which of the following is not an insectivorous plant

[AFMC 2004; J &amp; K CET 2010]

- (a) *Drosera* (b) *Nepenthes*  
(c) *Monotropa* (d) *Utricularia*

# NCERT

## Exemplar Questions

1. When a plant undergoes senescence, the nutrients may be [NCERT]

- (a) Exported (b) Withdrawn  
(c) Translocated (d) None of the above

2. Choose the correct option mycorrhiza is a symbiotic association of fungus with root system which helps in

- (A) Absorption of water (B) Mineral nutrition  
(C) Translocation (D) Gaseous exchange

Options:

- (a) Only (A) (b) Only (B)  
(c) Both (A) and (B) (d) Both (B) and (C)

3. Which one of the following roles is not characteristic of an essential element [NCERT]

- (a) Being a component of biomolecules  
(b) Changing the chemistry of soil  
(c) Being a structural component of energy related chemical compounds  
(d) Activation or inhibition of enzymes

4. Which one of the following statements can best explain the term critical concentration of an essential element [NCERT]

- (a) Essential element concentration below which plant growth is retarded  
(b) Essential element concentration below which plant growth becomes stunted  
(c) Essential element concentration below which plant remains in the vegetative phase  
(d) None of the above

5. Deficiency symptoms of an element tend to appear first in young leaves. It indicates that the element is relatively immobile. Which one of the following elemental deficiency would show such symptoms [NCERT]

- (a) Sulphur (b) Magnesium  
(c) Nitrogen (d) Potassium

6. Which one of the following symptoms is not due to manganese toxicity in plants [NCERT]

- (a) Calcium translocation in shoot apex is inhibited  
(b) Deficiency in both Iron and Nitrogen is induced  
(c) Appearance of brown spot surrounded by chlorotic veins  
(d) None of the above

7. Reaction carried out by  $N_2$  fixing microbes include [NCERT]

- (a)  $2NH_3 + 3O_2 \rightarrow 2NO_2^- + 2H^+ + 2H_2O$  (i)  
(b)  $2NO_2^- + O_2 \rightarrow 2NO_3^-$  (ii)

Which of the following statements about these equations is not true

- (a) Step (i) is carried out by *Nitrosomonas* or *Nitrococcus*  
(b) Step (ii) is carried out by *Nitrobacter*  
(c) Both steps (i) and (ii) can be called nitrification  
(d) Bacteria carrying out these steps are usually photoautotrophs

8. With regard to the Biological Nitrogen Fixation by *Rhizobium* in association with soyabean, which one of the following statement/statements does not hold true [NCERT]

- (a) Nitrogenase may require oxygen for its functioning  
(b) Nitrogenase is MO-Fe protein  
(c) Leg-haemoglobin is a pink coloured pigment  
(d) Nitrogenase helps to convert  $N_2$  gas into two molecules of ammonia

9. Match the element with its associated functions/roles and choose the correct option among given below

- A. Boron i. Splitting of  $H_2O$  to liberate  $O_2$  during photosynthesis  
B. Manganese ii. Needed for synthesis of auxins  
C. Molybdenum iii. Component of nitrogenase  
D. Zinc iv. Pollen germination  
E. Iron v. Component of ferredoxin

Options

[NCERT]

- (a) A-i, B-ii, C-iii, D-iv, E-v

- (b) A-iv, B-i, C-iii, D-ii, E-v

- (c) A-iii, B-ii, C-iv, D-v, E-i

- (d) A-ii, B-iii, C-v, D-i, E-iv

10. Plants can be grown in (Tick the incorrect option) [NCERT]

- (a) Soil with essential nutrients  
(b) Water with essential nutrients  
(c) Either water or soil with essential nutrients  
(d) Water or soil without essential nutrients

## Critical Thinking

### Objective Questions

1. Which of the following deficiency may cause leaf tip bending [BVP 2003]

- (a) Sulphur (b) Nitrogen  
(c) Phosphorus (d) Calcium

2. EDTA is much used in tissue cultures, it is a

- (a) Hormone (b) Vitamin  
(c) Buffer (d) Nutrient

3. Match the following and choose the correct combination from the options given

	Column I		Column II
A.	Potassium	1.	Constituent of ferredoxin
B.	Sulphur	2.	Involved in stomatal movement
C.	Molybdenum	3.	Needed in the synthesis of auxin
D.	Zinc	4.	Component of nitrogenase

[CBSE PMT 2003; Kerala PMT 2006, 10]

- (a) A-2, B-1, C-4, D-3 (b) A-1, B-2, C-3, D-4

- (c) A-4, B-3, C-2, D-1 (d) A-1, B-3, C-4, D-2

- (e) A-3, B-4, C-1, D-2

4. Minerals known to be required in large amounts for plant growth include [AIPMT (Cancelled) 2015]

(a) Calcium, magnesium, manganese, copper  
(b) Potassium, phosphorus, selenium, boron  
(c) Magnesium, sulphur, iron, zinc  
(d) Phosphorus, potassium, sulphur, calcium

5. Match the following mineral element with their deficiency symptom and choose the correct option

Column I		Column II	
A.	Calcium	1.	Chlorotic veins
B.	Potassium	2.	Delayed germination of seeds
C.	Zinc	3.	Necrosis of young leaves
D.	Iron	4.	Scorched leaf tips
E.	Phosphorous	5.	Malformed leaves

[Kerala PMT 2008]

(a) A-3, B-1, C-5, D-2, E-4  
(b) A-1, B-4, C-5, D-3, E-2  
(c) A-3, B-4, C-5, D-1, E-2  
(d) A-2, B-3, C-4, D-1, E-5  
(e) A-4, B-2, C-1, D-3, E-5

6. Which of the following is considered to be the best chemical method of fixing atmospheric nitrogen [BHU 2004]

(a) Fisher method  
(b) Decan method  
(c) Haber-Bosch method  
(d) Paranas-Meyerhoff method

7. Fly-ash is a/an [BHU 2004]

(a) Insectivorous plant  
(b) Light airborne particulate matter  
(c) New name of orchid plant  
(d) Causal organism of various diseases

8. Which one of the following is correctly matched

[CBSE PMT (Pre.) 2012]

(a) Passive transport of nutrients – ATP  
(b) Apoplast – Plasmodesmata  
(c) Potassium – Readily immobilisation  
(d) Bakane of rice seedlings – F. Skoog

9. On the basis of symptoms of chlorosis in leaves, a student inferred that this was due to the deficiency of nitrogen. This inference could be correct only if yellowing of leaves appeared first in [AIIMS 2007]

(a) Young leaves  
(b) Old leaves  
(c) Young leaves followed by old leaves  
(d) Old leaves followed by young leaves

10. *Aldrovanda* is

(a) Fly catcher plant (b) Water flea trap  
(c) Devil's foot (d) None of these

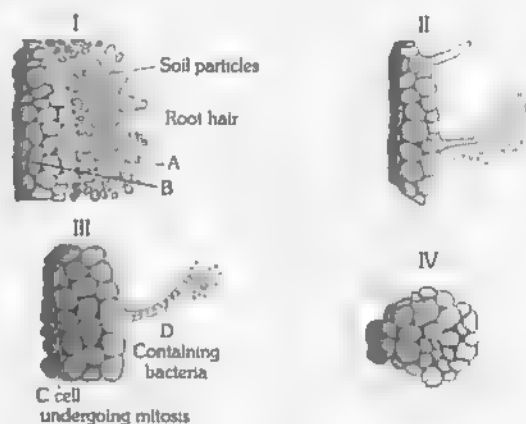
11. Which of the following shows that metabolic energy is required in the absorption of ions

(a) More ions absorption in presence of oxygen  
(b) Less absorption of ions in presence of oxygen  
(c) More ions absorption in presence of ATP  
(d) More ions absorption in presence of NAD

12. According to the well known theory of transport of solutes across a cell membrane, what happens when sugar is passed through it [CBSE PMT 1992]

(a)  $\text{Na}^+$  flows in the direction of the sugar  
(b)  $\text{Na}^+$  flows independent of sugar molecules  
(c)  $\text{Na}^+$  flows against the sugar molecules  
(d)  $\text{Na}^+$  ions do not flow at all

13. The given figure indicates the development of root nodule in soyabean



Identify A, B, C and D respectively [NCERT]

(a) A - *Nitrosomonas* bacteria; B - Cortex cell; C - Inner cortex; D - Infection thread  
(b) A - *Rhizobial* bacteria; B - Endodermal cell; C - Inner Endodermis; D - Infection thread  
(c) A - *Rhizobial* bacteria; B - Cortex cell; C - Inner cortex; D - Infection thread  
(d) A - *Rhizobial* bacteria; B - Cortex cell; C - Outer cortex; D - Infection thread

14. The smallest angiospermic/dicot parasite is [JIPMER 1997]

(a) *Arceuthobium* (b) *Wolffia*  
(c) *Cassytha* (d) *Rafflesia*

15. Fertility of the soil in rice fields can be improved by [MP PMT 1992]

(a) Gypsum (b) Sodium chloride  
(c) Blue-green algae (d) *Rhizobium*

# A Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

- (a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion  
 (b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion  
 (c) If the assertion is true but the reason is false  
 (d) If both the assertion and reason are false  
 (e) If the assertion is false but reason is true

1. Assertion : Plants lack excretory organs.  
Reason : Plant usually absorb essential nutrients and lead a passive life. [AIIMS 1997]
2. Assertion : Leguminous plants are nitrogen fixers.  
Reason : Leguminous plants have *Rhizobium* in their root nodules. [AIIMS 1997]
3. Assertion : Insectivorous habitat of plants is to cope up  $O_2$  deficiency.  
Reason : Insectivorous plants are partly autotrophic and partly heterotrophic. [AIIMS 1998]
4. Assertion : Use of fertilizers greatly enhances crop productivity.  
Reason : Irrigation is very important in increasing crop productivity. [AIIMS 2003]
5. Assertion : Hydroponics is used for solution culture.  
Reason : A balanced nutrient solution contains both essential and nonessential elements.
6. Assertion : The leaves of cauliflower become flaccid and brown in molybdenum deficiency.  
Reason : Cauliflower plant is affected by whiptail disease in molybdenum deficiency.
7. Assertion : In *Dionaea*, each lamina has marginal teeth.  
Reason : Marginal teeth of *Dionaea* help in prey capturing.
8. Assertion : Plants absorb nitrogen in the form of nitrate only.  
Reason : Nitrogen is the most critical element.
9. Assertion : Magnesium is important in photosynthesis and carbohydrate metabolism.  
Reason :  $Mg^{++}$  is involved in the synthesis of nucleic acids.
10. Assertion : Manganese is an activator of enzyme nitrite reductase.  
Reason : Manganese deficient cells prefer ammonia over nitrate
11. Assertion : Nitrogen-fixing bacteria in legume root nodules survive in oxygen-depleted cells of nodules.  
Reason : Leghaemoglobin completely removes oxygen from the nodule cells. [AIIMS 2004]
12. Assertion : Deficiency of sulphur causes chlorosis in plants.  
Reason : Sulphur is a constituent of chlorophyll, proteins and nucleic acids. [AIIMS 2004]

13. Assertion : Exanthema disease occurs due to deficiency of manganese.  
Reason : Reclamation is a disease of cereals.
14. Assertion : Iron is a microelement.  
Reason : Microelements are required in traces only, less than 1mg/gm of dry matter.
15. Assertion : In solution culture of plants, iron is added in the form of Fe-EDTA.  
Reason : Hydroponics set-up is costly.

# Answers

## General

1	a	2	c	3	a	4	c	5	b
6	c	7	d	8	d	9	b	10	c
11	d	12	d	13	d	14	b	15	a
16	d	17	d	18	c	19	d	20	c
21	a								

## Macro-Nutrients

1	c	2	b	3	c	4	d	5	b
6	d	7	d	8	d	9	a	10	b
11	d	12	a	13	d	14	a	15	c
16	c	17	a	18	c	19	d	20	b
21	b	22	a	23	c	24	c	25	b
26	a	27	d	28	c	29	d	30	d
31	a	32	a	33	b	34	a	35	d
36	c	37	a	38	a	39	a		

## Micro-Nutrients

1	b	2	b	3	d	4	d	5	a
6	a	7	c	8	a	9	d	10	a
11	c	12	c	13	a	14	b	15	a
16	c	17	b	18	a	19	d	20	d
21	c	22	b	23	b	24	a	25	a
26	d	27	a	28	b	29	d		

## Mineral absorption

1	a	2	c	3	b	4	a	5	b
6	a	7	a	8	d	9	a	10	a
11	c	12	a	13	b	14	b	15	d
16	c	17	c						

## Nitrogen nutrition

1	d	2	b	3	d	4	d	5	a
6	d	7	d	8	a	9	c	10	c
11	a	12	a	13	d	14	b	15	c
16	d	17	a	18	d	19	c	20	b
21	a	22	c	23	d	24	d	25	a
26	c	27	d						

## Special modes of nutrition

1	a	2	b	3	b	4	d	5	d
6	a	7	b	8	d	9	a	10	b
11	c	12	a	13	a	14	c	15	b
16	b	17	b	18	d	19	a	20	b
21	c	22	b	23	d	24	a	25	d
26	b	27	b	28	b	29	b	30	b
31	c								

## NCERT Exemplar Questions

1	b	2	c	3	b	4	a	5	a
6	b	7	d	8	a	9	b	10	c

## Critical Thinking Questions

1	a	2	c	3	a	4	d	5	c
6	c	7	b	8	c	9	c	10	b
11	c	12	a	13	c	14	a	15	c

## Assertion and Reason

1	a	2	a	3	e	4	b	5	c
6	a	7	a	8	e	9	b	10	a
11	c	12	c	13	e	14	a	15	b

# AS

## Answers and Solutions

## General

- (c) Major elements are required by plants in quantity of more than 1 milligram/gram dry matter and minor elements are required in quantity of less than 1 milligram/gram of dry matter.
- (c) An essential element is the one which has a specific structural or physiological role and without which plants cannot complete their life cycle.

- (d) Soilless production of plants is called hydroponics. A solution having all the essential elements in proper proportion is called normal or balanced nutrient solution.
- (b) Necrosis is death of cells of an area which therefore, becomes discoloured.
- (c) Tracer elements are radioactive isotopes of elements, which are used to detect various metabolic pathways in plants e.g.,  $C^{14}$ ,  $N^{15}$ ,  $P^{32}$ ,  $S^{35}$  etc.
- (a) Aeroponic plants are grown with their roots bathed in nutrient mist. This method has been successfully used in growing *Citrus* and olive plants.
- (d) Criteria for essentiality of elements were first of all given by Arnon.
- (d) The nutrient solution composition proposed by Knop (1865) and Arnon and Hoagland's (1940) are commonly used.
- (c) Etiolation is a type of growth exhibited by plants grown in darkness, usually in seed. They lack chlorophyll and therefore appears white or yellow.
- (a) Sand culture plants are grown in inert sand + nutrient solution. Main advantage is that roots get natural environment and proper aeration.

## Macro-Nutrients

- (b) Mg is present in centre of chlorophyll molecule head.
- (c) N and K are mobile elements.
- (b) Mg is an important constituent of chlorophyll molecule where it occupies a central position and essential for photosynthesis and Fe plays an important role in ETS, photosynthesis and respiration because iron is the part of cytochromes. It is also essential for chlorophyll synthesis.
- (d) According to Webster (1953) potassium is activator of more than 40 enzymes connected with phosphorylation, photosynthesis, starch synthesis, respiration, synthesis of chlorophyll, DNA and proteins.
- (d) Mg is chief element of chlorophyll molecule.
- (a) Magnesium is a component of porphyrin part of chlorophyll molecule.
- (b) Phosphorus is absorbed by the plants from the soil in the form of phosphate ions  $H_2PO_4^-$  and  $HPO_4^{2-}$  and nitrogen is absorbed by the plants in the form of nitrate ions ( $NO_3^-$ ).
- (d) Nitrogen, phosphorus and potassium are three critical elements which are essential for proper growth of plants e.g., crop plants.
- (a) Natural organic compounds are generally made up of carbon, hydrogen and oxygen.

14. (a) Boron has some role in the osmoregulation during the in vitro pollen germination. Boron is responsible for maintaining the solubility of calcium in cells.
15. (c) The foliage leaves are the first to suffer from its deficiency. Their tips become scorched and margins become dull yellow in colour.
16. (c) Carbon is absorbed in the form of carbon dioxide.
17. (a) Carbon, hydrogen and oxygen together constitute about 94% of the total dry weight of the plant. *Frame work elements* : C, H, N, O, P, S, these six elements are called as frame work elements which constitute the body of plants.
18. (c) Fertilizers providing N, P, K and minerals is called complete fertilizer. Nitrogen is necessary for dividing tissues, phosphorus is required for development of young tissue, growth of them, potassium is required in meristematic tissue, growing tips, leaves etc. The deficiency of N, P, K cause yellowing of leaves and premature death.
21. (b) Potassium is the commonest free in the cell and help to keep the cell electrically neutral and perhaps stabilises emulsions.
22. (a) Phosphorus plays an indispensable role in energy metabolism i.e., hydrolysis of pyrophosphate and various organic phosphate bonds being used to drive chemical reactions. Thus it is required for all phosphorylation reactions.
23. (c) Sulphur is relatively immobile and therefore, deficiency symptoms appear first in young leaves.
24. (c) In plant ash, nitrogen is not present because it releases out as its oxide when heated upto  $600^{\circ}\text{C}$  to obtain plant ash, however it is an essential element.
25. (b) Phosphorus is absorbed by the plants from the soil in the form of phosphate ions  $\text{H}_2\text{PO}_4^-$  and  $\text{HPO}_4^{2-}$ .
26. (a) Mo, Mn and Zn are microelements.
27. (d) Calcium is essential for fat metabolism, carbohydrate metabolism, nitrate assimilation and binding of nucleic acid with proteins.
28. (c) Magnesium occurs in the soil in the form of magnesite ( $\text{MgCO}_3$ ), dolomite ( $\text{MgCO}_3, \text{CaCO}_3$ ), magnesium sulphate ( $\text{MgSO}_4$ ) and as silicates. It is absorbed from the soil in form of ions ( $\text{Mg}^{++}$ ).
30. (d) Phosphorus deficiency causes premature leaf fall and leaves become dark to blue-green in colour.
31. (a) Iron occurs in the concentration of less than 1 mg/gm. However, its essentiality was discovered along with other macroelements long before microelements were found to be required. Therefore, it is often regarded to be macroelement.
32. (a) Onion and its relatives also possess antimicrobial sulphur containing compounds allicin and diallylsulphide. Tear promoting substance is also a sulphur compound propanethial sulphenic oxide. Reduced meristematic activity and chlorotic leaves produce tea yellow disease of tea plants.
33. (b) Calcium stimulates development of root hairs.
34. (a) Meristematic regions found in stem, leaf and root tips are greatly affected by the absence of calcium because it is not rapidly translocated to these regions. Ultimately they die and thus stop the growth of these organs. Calcium involved in selective permeability of cell membranes. It activates certain enzymes required for development of stem and root apex and as calcium pectate in the middle lamella of the cell wall.
36. (c) Nucleotide is made up by nitrogen base + sugar (ribose or deoxyribose) + phosphate.
38. (a) Phosphorus promotes healthy root growth and fruit ripening by helping translocation of carbohydrates.

### Micro-Nutrients

1. (b) They are those essential elements which are required by plants in traces only, equal or less than 0.1 mg/gm of dry matter. They are eight in number – Fe, Zn, Mn, B, Cu, Mo, Cl and Ni.
2. (b) Micro-nutrients are present in less amount in plants but they are as important as macro-nutrients.
3. (d) Mottled chlorosis with marginal necrosis and infolding, lamina or upper half of lamina falls down (whiptail disease) due to the deficiency of molybdenum.
5. (a) Cu deficiency causes necrosis of the tip of the young leaves (e.g., Citrus). The disease is called 'die back'.
7. (c) Some minerals are either components of enzymes, their cofactors or activators, e.g.,  $\text{Ni}_2+$ .
8. (a) Zinc is a cofactor for carboxypeptidases.
9. (d) Some of the physiological diseases caused due to boron deficiency are internal cork of apple, top rot of tobacco. These diseases can be cured by application of small doses of sodium tetraborate in the soil.
11. (c) The leaves become distorted and sickle shaped and get clustered to form rosettes. This effect is known as 'little leaf disease'.
12. (c) Its deficiency causes 'whiptail disease' in cauliflower and cabbage. The leaves first show an interveinal mottling and the leaf margins may become gray and flaccid and finally brown.
13. (a) Boron is absorbed by the plants as borate it is involved in the transport of carbohydrates (Sugar).
15. (a) Cu-Copper takes part in electron transport as plastocyanin (between PS II and PSI) and cytochrome to oxygen.

Mg-Manganese is activator of a number of enzymes like reductases, oxidases, etc. taking part in respiration and photosynthesis.

Fe – Iron is component of  $e^-$  transferring biomolecules like cytochromes and ferredoxin. They are essential components of photosynthesis.

16. (c) Many elements become toxic in higher concentration than the normal e.g., Cu. Others are toxic even in smaller concentration e.g., Hg
17. (b) Iron deficient plants develop pronounced interveinal chlorosis similar to that caused by Mg deficiency. Whereas in iron chlorosis the young leaves may become yellow or white with prominent green veins.
19. (d) "Grey speck disease" in oat appears due to the deficiency of manganese, which leads to total failure of crop.
20. (d) Calcium is required by plants in larger amounts hence it is called macro or tracer element.
22. (b) Recent research has shown that some elements, such as cobalt, vanadium and nickel, may be essential for certain plants in very small amounts.
23. (b) Zinc is absorbed by the plants in ionic form.
24. (a) Micro-elements are mostly involved in the functioning of enzymes, as cofactors or metal activators.
25. (a) Molybdenum is required for nitrogen fixation. Nitrate metabolism depends upon enzyme nitrate reductase. It is an activator of nitrate reductase. Therefore, the element is important for nitrogen fixation.
26. (d) Cu ( $6 \mu\text{m/gm}$ ), Zn ( $20 \mu\text{m/gm}$ ) and Mo ( $.1 \mu\text{m/gm}$ ) are required for plant growth.
28. (b) Molybdenum is component of nitrogenase and it also acts as enzyme activator for nitrate reductase.
29. (d) Ferredoxin is Fe having electron carrier which participates in photosynthesis. It plays an important role in ETS, photosynthesis and respiration because iron is the part of cytochromes.
11. (c) The ash that is left after burning any dry part of the plant in a crucible, contains only mineral elements and is called plant ash.
12. (a) Maximum mineral salt absorption occurs by zone of elongation. No mineral salt absorption occurs by root hair zone. Mineral salt absorption occurs directly by cells of epiblema and not by root hair.
15. (d) In this process an ATP is used up. ATP molecule combine with carrier molecules and allow passage of substances against concentration gradient.
16. (c) At  $0^\circ\text{C}$ , 5 gm ions are absorbed and at  $20^\circ\text{C}$ , 20gm ions are absorbed.  
Energy is increased from  $0^\circ\text{C}$  to  $20^\circ\text{C}$ , then the increase in ion absorption amount =  $20 - 5 = 15 \text{ gm}$ .

### Nitrogen nutrition

### Mineral absorption

1. (a) Because inorganic materials move with water.
2. (c) The use of energy of ATP in transferring solutes across membrane may be through an ATPase which creates a pH gradient across the membrane.
3. (b) It is mode of mineral absorption which involves expenditure of metabolic energy. Energy is generally obtained from ATP.
4. (a) The semipermeable membrane is responsible for absorption of mineral salts.
6. (a) Mineral salts are absorbed mostly in form of ions, i.e., anions and cations. Ions are accumulated by the plants against their concentration in the soil.
7. (a) The carrier proteins usually transport solutes against their electrochemical gradient. Energy for transport is provided by ATP, electron transport chain and light.
9. (a) This type of absorption is carried out by purely physical forces.
1. (d) Chief source of nitrogen for plants are the nitrates of calcium and potassium.
3. (d) Nitrogen excess in soil cause susceptibility towards pathogen like fungi, bacteria.
4. (d) The deficiency of nitrogen causes chlorosis in leaves of the plants and the cell division as well as cell elongation is stopped, due to which plants remain dwarf and production of flowers, fruits and seeds is decreased.
6. (d) Nitrogen is absolutely essential for the synthesis of protein. In addition nitrogen is found in such important molecules as aminoacids, purines, pyrimidines etc. Purines, pyrimidines, RNA and DNA which are essential for protein synthesis.
11. (a) Nitrogenase require high input of energy and anaerobic condition.
12. (a) The bacterium *Rhizobium leguminosarum* lives symbiotically in the root of pea. This bacteria are responsible for the nitrogen fixation.
14. (b) Nitrogen fixing bacteria as *Rhizobium* have symbiotic relationship with the roots of gram (leguminous) plants. This association produce nodules on roots.
15. (c) The bacteria (*Rhizobium* sps) associated with the root nodules of legumes fix atmospheric nitrogen. It helps in increase of soil fertility because they are rich in nitrogen and adds nitrates in the soil.
16. (d) The bacterium *Rhizobium* infects the roots through the root hairs of groundnut plant and reproduce in the cells of cortex of roots. Simultaneously the division of cortex cells take place due to which the nodules are formed in the root.
19. (c) The important elements need to be replenished in crop fields are nitrogen, phosphorus and potassium. These are grouped as nitrogenous fertilizers, phosphate fertilizers and potash fertilizers. These are abbreviated as NPK.

21. (a) Nif gene is present in *Rhizobium*. It is responsible for the synthesis of enzyme nitrogenase which can fix atmospheric nitrogen. *Rhizobium leguminosarum* bacteria is found symbiotically associated in the root nodules of leguminous plant.
22. (c) Some bacteria such as *Thiobacillus denitrificans*, *Pseudomonas aeruginosa* and *Micrococcus denitrificans* also occur in the soil which convert the nitrate and ammonia into atmospheric free elemental nitrogen.
23. (d) Frankia is symbiont in root nodules of several nonlegume plants like *Casuarina* and *Alnus* (Alder).
24. (d) Nitrogenase is sensitive against  $O_2$ .
13. (a) The common example of partial root parasite is *Santalum album*. Which is an evergreen partial root parasite. It grows on the roots of *Dalbergia sisso*, *Eucalyptus*
14. (c) The leaves are modified into pitchers. The pitchers of *Sarracenia* lack digestive enzymes and here the insects are decomposed by bacteria.
16. (b) Epiphytic roots develop in some orchids which grow as epiphytes upon the trunk or branches of trees. They absorb moisture with the help of special sponge like tissue called velamen.
17. (b) *Dionaea* (Venus Fly Trap) is an American herb that possesses a rosette of long-petioled leaves
19. (a) It is a total root parasite. The plant body consists of fine threads resembling hyphae of fungal mycelia. It lies completely inside the root of the host. It grows directly on the roots of *Cissus* and Figs.
21. (c) These insects die in the bladder and are decomposed in due course of time. After decomposition the nitrogenous substances are absorbed through the hair of bladder.
22. (b) A heterotrophic plant which obtains its food from other living organism without killing it, is called a parasite. The parasite sucks its food from the host with the help of specialized absorbing organs called haustoria.
23. (d) Because they grow in marshy or muddy soils, which are generally deficient in nitrogen. Plants usually grow in nitrogen deficient soils and fulfil their nitrogen requirement by digesting insects.
24. (a) *Nepenthes khasiana* is a green plant (photosynthetic plant) but shows heterotrophic nature for nitrogen supply, therefore, is called as carnivorous.
25. (d) Halophytes are those plants which grow in saline habitats, i.e., in salty marshes, alkaline soil etc. In halophytes the water is present in sufficient amount but due to high osmotic concentrations it is physiologically not available to normal plants. Such conditions are said to be physiologically dry e.g. *Spartina*, *Atriplex*, *Portulaca*.
27. (b) *Dischidia* : The pitcher is without lid and is used only for storing rain water with some mud.
30. (b) Carnivorous plants (Pitcher plant) are green plants. They manufacture their food themselves. Hence are autotrophic in nature. They behave like heterotrophic organisms for supplementing their nitrogen supply only through catching and digesting small animals like insects. Insect captured by carnivorous plants (*Drosera* and *Sarracenia*) partially meet their requirement of nitrogen.
31. (c) *Monotropa*, though usually referred to as a saprophyte, actually gets its nourishment from fungal mycelium, which surround its roots. Such association between roots of higher plants and fungi is known as mycorrhiza.

### Special modes of nutrition

1. (a) Autotrophs are green plants capable of synthesizing their own food from raw material ( $CO_2$ , water and sunlight). Thus they are independent and self nourishing.
2. (b) The heterotrophs, require both organic and inorganic substances from outside. All nongreen plants and animals, including human beings are heterotrophs.
4. (d) Epiphytes are plants which live on other plants for space (shelter/support) only. They are therefore, called space parasites.
5. (d) Partial parasite plants have chlorophyll and therefore, synthesize their organic food themselves. But they fulfil their mineral and water requirements from their host plants e.g., *Viscum*.
6. (a) *Cuscuta* is found on outer side of the host and are total stem parasite.
7. (b) *Viscum album* is a partial stem parasite that grows on silverfish, poplar, apple, walnut, oak etc. The parasite sends a primary haustorium into the host for sucking food.
9. (a) Insectivorous plants usually grow in water logged and swampy soil deficient in nitrogen compounds. These plants leaves trap and digest the insects and other small animals to get their nitrogen requirements.
10. (b) *Loranthus* is another partial stem parasite. *Loranthus* is similar to *viscum* growing on *Acacia*, *Mango*, *Dalbergia*, *Albizia* etc
11. (c) *Drosera* is a herbaceous plant. These long special hair are generally referred to as tentacles. The glandular heads of the tentacles secrete sticky juice. Insect is attracted by the sticky fluid and tries to sit on the leaf, it becomes entangled in the sticky fluid.
12. (a) *Orbanche* is usually parasitic upon brinjal, tobacco. *Balanophora* occurs as a total root parasite in the roots of forest trees. *Rafflesia* is a total root parasite plant on Fig, *Cissus* and several other forest trees. They are largest with a diameter of 1m and weight of 11kg

## Critical Thinking Questions

1. (a) Sulphur deficiency causes chlorosis in young leaves. Leaf tips and margins roll downwards and inwards. e.g., Tomato, Tea etc.
2. (c) EDTA is buffer solution and it maintains the pH of culture medium.
6. (c) Haber-bosch method is the best chemical method for fixing of nitrogen.
7. (b) Fly-ash is a light airborne particulate matter. Coal also produces mineral ash. Some of which is discharged as fly ash.
9. (c) Chlorosis is the main symptom of nitrogen deficiency. As a result, the leaves gradually become pale or yellow. These symptoms first appear in old leaves and later in young leaves.
10. (b) *Aldrovanda* (Water flea trap) is an aquatic free floating rootless insectivorous plant which possesses leaves similar to those of *Dionaea*.
11. (c) The absorption of ions, involving use of metabolic energy is called active absorption. Energy is generally obtained from ATP. Therefore, active absorption is linked to hydrolysis of ATP.
14. (a) *Arceuthobium* is the smallest angiospermic parasite. It is total parasite that grows on a number of forest trees including *Pinus* and *Juniper*.
15. (c) *Aulosira fertilissima* (Blue-green algae) is an important nitrogen fixer of rice fields.
6. (a) Cauliflower plants very commonly show whiptail disease. The leaves first show an interveinal mottling and the leaf margins may become gray and flaccid and finally brown.
7. (a) The upper surface of each lamina lobe of *Dionaea* contains 3 sensitive spines. The leaf margin bears 12-20 curved spiny teeth. The marginal teeth get interlocked. So the prey cannot escape. It is digested by the secretion of reddish glands.
8. (e) Plants absorb nitrogen in the form of  $\text{NO}_3^-$  (nitrate) or  $\text{NH}_4^+$  (ammonium ion). They can absorb  $\text{NO}_2^-$  (nitrite) as well but the same does not accumulate in the soil. Only a small quantity of nitrate or ammonium is available in the lithosphere. Therefore, nitrogen is the most critical element. Other critical elements are phosphorus and potassium.
9. (b) Magnesium is a constituent of the chlorophyll molecule, without which photosynthesis would not occur. Many of the enzymes involved in carbohydrate metabolism require magnesium as an activator. Magnesium is also an activator for those enzymes involved in the synthesis of nucleic acids (DNA, RNA) from nucleotide polyphosphate.
10. (a) Manganese plays an important role in nitrate reduction. Manganese acts as an activator for the enzymes nitrite reductase and hydroxylamine reductase. The preference of ammonia over nitrate as a nitrogen source by the manganese-deficient cells supports the above mentioned analysis of the role of manganese.
11. (c) *Rhizobium* species (e.g., *Leguminosarum*, *R. lupini* etc.) live in symbiotic association in the root nodules of leguminous plants like, pea, gram etc. In the soil the bacteria cannot fix nitrogen. After entering the legume root, the bacterium induces cell membrane. A pink-red pigment called leghaemoglobin lines the membrane and protects the bacteroids from the oxygen.

## Assertion and Reason

1. (a) Plants absorb essential nutrients from soil hence they lack excretory organs. Particulate matter is not taken as these lack mouth.
2. (a) Leguminous plants have nodulated roots in which *Rhizobium* is present. So, these are able to fix nitrogen.
3. (e) Insectivorous plants are autotrophic and heterotrophic as they capture insects to overcome their  $\text{N}_2$  deficiency.
4. (b) Among the sixteen essential plant nutrients nitrogen, phosphorus and potash are the most common nutrients found deficient in Indian soil. Supply of these nutrients to soil artificially through fertilizers is necessary to keep the soil rich in plant nutrients for achieving maximum yield. Irrigation practices also helpful in enhancing the crop yield. In this way both fertilizers and irrigation are equally important for high crop yield.
5. (c) Solution culture is being used for raising flowers and vegetables at home. This soilless production of plants is called hydroponics. A solution having all the essential elements in proper proportion is called normal or balanced nutrient solution.
12. (c) Due to deficiency of sulphur plant shows chlorosis (i.e., yellowing due to degradation of chlorophyll) followed by anthocyanin development. The younger leaves show chlorosis before older ones. Sulphur is not the constituent of chlorophyll. The main constituent of chlorophyll is magnesium.
13. (e) The most important diseases due to copper deficiency are exanthema and reclamation. Exanthema is a disease of fruit tree. Reclamation is disease of cereals that occurs chiefly on newly reclaimed peat land.
14. (a) Micro elements are those essential elements which are required by plants in traces only, less than 1 mg/gm of dry matter. Iron occurs in the concentration of less than 1 mg/gm.
15. (b) In solution culture, iron is added as Fe-EDTA. The agent which keeps metals in the soluble state is called chelating agent or ligand. Fe-EDTA complex is called chelate. The soilless production of plants is called solution culture or hydroponics. The cost of setting up a hydroponic system is very high.



## Mineral Nutrition

## Self Evaluation Test

- The element which is required by the sea plants is  
(a) Cobalt (b) Zinc  
(c) Copper (d) Sodium
- The ability of the venus fly trap of capture insects is due to  
[CBSE PMT 2005]  
(a) Chemical stimulation by the prey  
(b) A passive process requiring no special ability on the part of the plant  
(c) Specialized "muscle-like" cells  
(d) Rapid turgor pressure changes
- It is possible to determine whether an element is essential by observing growth of plants [AIIEE Pharmacy 2004]  
(a) On soil from which the particular element is removed  
(b) On soil in which only the particular element is present  
(c) On an inert medium to which solution of only the particular element is added  
(d) On an inert medium to which a nutrient solution excluding that particular element, is added
- Which statement is wrong  
(a) Plants take very little amount of mineral elements from soil  
(b) Plants absorb one thing at a time either water or mineral salt  
(c) Root hair absorb water and minerals together  
(d) Mineral absorption primarily takes place by active method
- Chlorosis, etiolation and albinism are caused by the deficiency of [JIPMER 1994]  
(a) Iron, light and certain genes  
(b) Zinc, iron and magnesium  
(c) Magnesium, iron, zinc, light and certain genes  
(d) Magnesium, zinc and light
- The association between ants and members of family rubiaceae is [AMU (Med.) 1997; MP PMT 2013]  
(a) Ornithophily (b) Entomophily  
(c) Myrmecophily (d) Anemophily
- A trace element essential for plant growth and radioactive isotope which is used in cancer therapy is known as  
(a) Cobalt (b) Iron  
(c) Calcium (d) Sodium
- The enzyme commonly presents in insectivorous plants to fulfil the need of their specific habit  
(a) Trypsin (b) Pepsin  
(c) Pectinase (d) Cellulase
- An example of a parasitic plant that is also strictly epiphytic is  
(a) *Cuscuta* (dodder) (b) *Viscum* (mistletoe)  
(c) *Rafflesia* (d) *Orobancha*

## S Answers and Solutions

1	d	2	d	3	d	4	b	5	c
6	c	7	a	8	b	9	b		

- (d) In *Dionaea* (Venus Fly Trap) an insect that happens to alight over the lamina and touch a sensitive spine twice in quick succession, causes the folding of the lamina. The curved marginal spines get interlocked and the insect gets trapped.
- (c) The ants obtain food and shelter from the plant and they protect the plant from other animals.
- (b) The insect is killed and its proteins are digested by pepsin.
- (b) *Viscum* is a partial stem parasite with edible berries having sticky pulp.



## Chapter 4.3

# Photosynthesis in Higher Plants

In photosynthesis process, 'energy rich compounds like carbohydrates are synthesized from simple inorganic compounds like carbon dioxide and water in the presence of chlorophyll and sunlight with liberation of oxygen'. The process of photosynthesis can also be defined as "transformation of photonic energy (i.e., light or radiant energy) into chemical energy".

About 90% of total photosynthesis in world is done by algae in oceans and in freshwater. More than 170 billion tonnes of dry matter are produced annually by this process. Further  $\text{CO}_2$  fixed annually through photosynthesis is about  $7.0 \times 10^{13} \text{ kg}$ . Photosynthesis is a reductive, anabolic and endothermic reaction. Photosynthesis helps to maintain the equilibrium position of  $\text{O}_2$  and  $\text{CO}_2$  in the atmosphere.

### Historical background

Before seventeenth century it was considered that plants take their food from the soil.

□ **Van Helmont** (1648) concluded that all food of the plant is derived from water and not from soil.

□ **Stephen Hales** (Father of Plant Physiology) (1727) reported that plants obtain a part of their nutrition from air and light may also play a role in this process.

□ **Joseph Priestley** (1772) demonstrated that green plants (mint plant) purify the foul air (i.e., Phlogiston), produced by burning of candle, and convert it into pure air (i.e., Dephlogiston).

□ **Jan Ingen-Housz** (1779) concluded by his experiment that purification of air was done by green parts of plant only and that too in the presence of sunlight. Green leaves and stalks liberate dephlogisticated air (Having  $\text{O}_2$ ) during sunlight and phlogisticated air (Having  $\text{CO}_2$ ) during dark.

□ **Jean Senebier** (1782) proved that plants absorb  $\text{CO}_2$  and release  $\text{O}_2$  in the presence of light. He also showed that the rate of  $\text{O}_2$  evolution depends upon the rate of  $\text{CO}_2$  consumption.

□ **Nicolas de Saussure** (1804) showed the importance of water in the process of photosynthesis. He further showed that the amount of  $\text{CO}_2$  absorbed is equal to the amount of  $\text{O}_2$  released.

□ **Julius Robert Mayer** (1845) proposed that light has radiant energy and this radiant energy is converted to chemical energy by plants, which serves to maintain life of the plants and also animals.

□ **Liebig** (1845) indicated that main source of carbon in plants is  $\text{CO}_2$ .

□ **Bousingault** (1860) reported that the volume of  $\text{CO}_2$  absorbed is equal to volume of  $\text{O}_2$  evolved and that  $\text{CO}_2$  absorption and  $\text{O}_2$  evolution get start immediately after the plant was exposed to sunlight.

□ **Julius Von Sachs** (1862) demonstrated that first visible product of photosynthesis is starch. He also showed that chlorophyll is confined to the chloroplasts.

□ **Melvin Calvin** (1954) traced the path of carbon in photosynthesis (Associated with dark reactions) and gave the  $\text{C}_3$  cycle (Now named Calvin cycle). He was awarded Nobel prize in 1961 for the technique to trace metabolic pathway by using radioactive isotope.

□ **Huber, Michel and Deisenhofer** (1985) crystallised the photosynthetic reaction center from the purple photosynthetic bacterium, *Rhodospseudomonas viridis*. They analysed its structure by X-ray diffraction technique. In 1988 they were awarded Nobel prize in chemistry for this work.

## Photosynthesis in higher plants

**Chloroplast (The site of photosynthesis) :** Chloroplast are green plastids which function as the site of photosynthesis in eukaryotic photoautotrops. It fixes  $\text{CO}_2$  into carbohydrate.

Photosynthetic unit can be defined as number of pigment molecules required to affect a photochemical act, that is the release of a molecule of oxygen. Park and Biggins (1964) gave the term quantasome for photosynthetic units which is equivalent to 230 chlorophyll molecules.

**Chloroplast pigments :** Pigments are the organic molecules that absorb light of specific wavelengths in the visible region due to presence of conjugated double bonds in their structures. The chloroplast pigments are fat soluble and are located in the lipid part of the thylakoid membranes (fret membrane). There is a wide range of chloroplastic pigments which constitute more than 5% of the total dry weight of the chloroplast. They are grouped under two main categories :

(1) **Chlorophylls :** Chlorophyll 'a' is found in all the oxygen evolving photosynthetic plants except photosynthetic bacteria. Reaction centre of photosynthesis is formed of chlorophyll a. It occurs in several spectrally distinct forms which perform distinct roles in photosynthesis (e.g.,  $\text{Chl } a_{680}$  or  $P_{680}$ ,  $\text{Chl } a_{700}$  or  $P_{700}$ , etc.). It directly takes part in photochemical reaction. Hence, it is termed as primary photosynthetic pigment. Other photosynthetic pigments including chlorophyll b, c, d and e ; carotenoids and phycobilins are called accessory pigments because they do not directly take part in photochemical act. They absorb specific wavelengths of light and transfer energy finally to chlorophyll a through electron spin resonance.

Chlorophyll a is bluish-green while chlorophyll b is olive-green. Both are soluble in organic solvents like alcohol, acetone etc. Chlorophyll is a green pigment because it does not absorb green light (but reflect green light) Chlorophyll a ( $\text{C}_{55}\text{H}_{72}\text{O}_5\text{N}_4\text{Mg}$ ) possesses —  $\text{CH}_3$  (methyl group), which is replaced by —  $\text{CHO}$  (an aldehyde) group in chlorophyll b ( $\text{C}_{55}\text{H}_{70}\text{O}_6\text{N}_4\text{Mg}$ ). Chlorophyll molecule is made up of a squarish tetrapyrrolic ring known as head and a phytol alcohol called tail. The magnesium atom is present in the central position of tetrapyrrolic ring. The four pyrrole rings of porphyrin head are linked together by methine ( $\text{CH} =$ ) groups forming a ring system.

When central  $\text{Mg}$  is replaced by  $\text{Fe}$ , the chlorophyll becomes a green pigment called 'cytochrome' which is used in photosynthesis (Photophosphorylation) and respiration both.

(2) **Carotenoids :** They are sometimes called lipochromes due to their fat soluble nature. They are lipids and found in non-green parts of plants. Light is not necessary for their biosynthesis. Carotenoids mainly absorb violet, indigo and blue wavelength of spectrum in higher plants and transfer it to  $\text{Chl. a}$  and thus act as accessory pigments. They protect the chlorophyll molecules from photo-oxidation by picking up nascent oxygen and converting it into harmless molecular stage. Carotenoids can be classified into two groups namely carotenes and xanthophyll.

(i) **Carotenes :** They are orange red in colour and have general formula  $\text{C}_{40}\text{H}_{56}$ . They are isolated from carrot.

They are found in all groups of plants i.e., from algae to angiosperms. Some of the common carotenes are  $\alpha$ ,  $\beta$ ,  $\gamma$  and  $\delta$  carotene; phyotene, lycopene, neurosporene etc. The lycopene is a red pigment found in ripe tomato and red pepper fruits. The  $\beta$ -carotene on hydrolysis gives vitamin A, hence the carotenes are also called provitamin A.  $\beta$ -carotene is black yellow pigment of carrot roots

(ii) **Xanthophylls :** They are yellow coloured carotenoid also called xanthols or carotenols. They contain oxygen also along with carbon and hydrogen and have general formula  $\text{C}_{40}\text{H}_{56}\text{O}_2$ .

**Lutein ( $\text{C}_{40}\text{H}_{56}\text{O}_2$ )** a widely distributed xanthophyll which is responsible for yellow colour in autumn foliage. Fucoxanthin ( $\text{C}_{40}\text{H}_{56}\text{O}_6$ ) is another important xanthophyll present in Phaeophyceae (Brown algae).

(3) **Phycobilins :** These pigments are mainly found in blue-green algae (Cyanobacteria) and red algae. These pigments have open tetrapyrrolic in structure and do not bear magnesium and phytol chain.

Blue-green algae have more quantity of phycocyanin and red algae have more phycoerythrin. Phycocyanin and phycoerythrin together form phycobilins. These water soluble pigments are thought to be associated with small granules attached with lamellae. Like carotenoids, phycobilins are accessory pigments i.e., they absorb light and transfer it to chlorophyll a.

**Nature of light :** Sunlight is a type of energy called radiant energy or electromagnetic energy. This energy, according to electromagnetic wave theory (Proposed by James Clark Maxwell, 1960), travels in space as waves. The distance between the crest of two adjacent waves is called a wavelength ( $\lambda$ ). Shorter the wavelength greater the energy.

The unit quantity of light energy in the quantum theory is called quantum ( $h\nu$ ), whereas the same of the electromagnetic field is called photon. Solar radiation can be divided on the basis of wavelengths. Radiation of shortest wavelength belongs to cosmic rays whereas that of longest wavelength belong to radio waves. Visible light lies between wavelengths of ultra-violet and infra-red. The visible spectrum of solar radiations are primarily absorbed by carotenoids of the higher plants are violet and blue. However, out of blue and red wavelengths, blue light carry more energy.

Shortest wavelength —————→ Longest wavelength  
Maximum energy Minimum energy

**Visible light :** 390nm (3900Å) to 760nm (7600Å). Violet (390–430nm), blue (430–470nm), blue-green (470–500nm), green (500–580nm), yellow (580–600nm), orange (600–650nm), orange-red (650–660nm) and red (660–760nm) Far-red (700–760nm). Infra-red 760nm – 100µm. Ultraviolet 100–390nm. Solar radiations 300nm (ultraviolet) to 2600nm (infra-red).

Photosynthetically active radiation (PAR) is 400–700nm. Leaves appear green because chlorophylls do not absorb green light. The same is reflected and transmitted through leaves.

**Absorption and action spectra :** The curve representing the light absorbed at each wavelength by pigment is called absorption spectrum. Curve showing rate of photosynthesis at different wavelengths of light is called action spectrum.

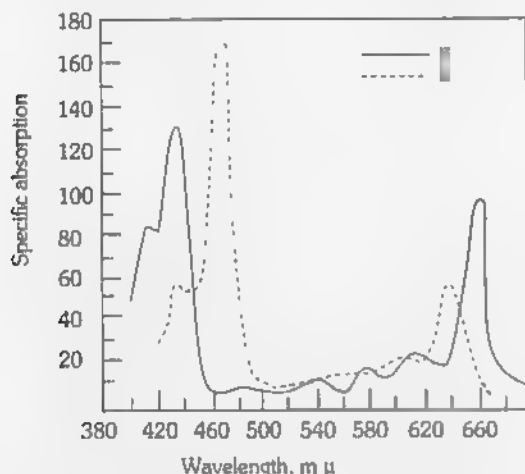


Fig : 4.3-1 Absorption spectra of chlorophylls a and b

Absorption spectrum is studied with the help of spectrophotometer. The absorption spectrum of chlorophyll a and chlorophyll b indicate that these pigments mainly absorb blue and red lights. (430 nm and 662 nm for chlorophyll a, 455 nm and 644 nm for chlorophyll b). Action spectrum shows that maximum photosynthesis takes place in blue and red regions of spectrum. The first action spectrum of photosynthesis was studied by T.W. Engelmann (1882) using green alga *Spirogyra* and oxygen seeking bacteria.

In this case actual rate of photosynthesis in terms of oxygen evolution or carbon dioxide utilisation is measured as a function of wavelength

### Mechanism of photosynthesis

On the basis of discovery of Nicolas de Saussure that "The amount of  $O_2$  released from plants is equal to the amount of  $CO_2$  absorbed by plants", it was considered that  $O_2$  released in photosynthesis comes from  $CO_2$ , but Ruben proved that this concept is wrong.

In 1930, C.B. Van Niel proved that, sulphur bacteria use  $H_2S$  (in place of water) and  $CO_2$  to synthesize carbohydrates as follows:

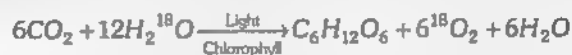


This led Van Niel to the postulation that in green plants, water ( $H_2O$ ) is utilized in place of  $H_2S$  and  $O_2$  is evolved in place of sulphur (S). He indicated that water is an electron donor in photosynthesis.



This was confirmed by Ruben and Kamen in 1941 using *Chlorella* a green alga.

They used isotopes of oxygen in water, i.e.,  $H_2^{18}O$  instead of  $H_2O$  (normal) and noticed that liberated oxygen contains  $^{18}O$  of water and not of  $CO_2$ . The overall reaction can be given as under :



During photosynthesis the  $O_2$  in glucose comes from carbondiowater.

### Modern concept of photosynthesis

Photosynthesis is an oxidation reduction process in which water is oxidised to release  $O_2$  and  $CO_2$  is reduced to form starch and sugars.

Scientists have shown that photosynthesis is completed in two phases.

(1) **Light phase or Photochemical reactions or Light dependent reactions or Hill's reactions :** During this stage energy from sunlight is absorbed and converted to chemical energy which is stored in ATP and  $NADPH + H^+$ .

(2) **Dark phase or Chemical dark reactions or Light independent reactions or Blackman reaction or Biosynthetic phase :** During this stage carbohydrates are synthesized from carbon dioxide using the energy stored in the ATP and NADPH formed in the light dependent reactions.

Evidence for light and dark reactions in photosynthesis :

(1) **Physical separation of chloroplast into grana and stroma fractions :** It is now possible to separate grana and stroma fractions of chloroplast. If light is given to grana fraction in presence of suitable H-acceptor and in complete absence of  $CO_2$ , then ATP and  $NADPH_2$  are produced (i.e., assimilatory powers). If these assimilatory powers (ATP and  $NADPH_2$ ) are given to stroma fraction in presence of  $CO_2$  and absence of light, then carbohydrates are formed.

(2) **Experiments with intermittent light or Discontinuous light :** Rate of photosynthesis is faster in intermittent light (Alternate light and dark periods) than in continuous light. It is because light reaction is much faster than dark reaction, so in continuous light, there is accumulation of ATP and  $NADPH_2$  and hence reduction in rate of photosynthesis but in discontinuous light, ATP and  $NADPH_2$  formed in light are fully consumed during dark in reduction of  $CO_2$  to carbohydrates. Accumulation of  $NADPH_2$  and ATP is prevented because they are not produced during dark periods

(3) **Temperature coefficient studies :** Blackman found that  $Q_{10}$  was greater than 2 in experiment when photosynthesis was rapid and that  $Q_{10}$  dropped from 2 often reaching unity, i.e., 1 when the rate of photosynthesis was low. These results show that in photosynthesis there is a dark reaction ( $Q_{10}$  more than 2) and a photochemical or light reaction (with  $Q_{10}$  being unity).

$$Q_{10} = \frac{\text{Reaction rate of } (t + 10)^\circ C}{\text{Reaction at } t^\circ C}$$

**Light reaction (Photochemical reactions) :** Light reaction occurs in grana fraction of chloroplast and in this reaction are included those activities, which are dependent on light. Assimilatory powers (ATP and  $NADPH_2$ ) are mainly produced in this light reaction.

**Robin Hill** (1939) first of all showed that if chloroplasts extracted from leaves of *Stellaria media* and *Lamium album* are suspended in a test tube containing suitable electron acceptors, e.g., Potassium ferrioxalate (Some plants require only this chemical) and potassium ferricyanide, oxygen is released due to photochemical splitting of water. Under these conditions, no  $CO_2$  was consumed and no carbohydrate was produced, but light-driven reduction of the electron acceptors was accompanied, by  $O_2$  evolution.



The splitting of water during photosynthesis is called photolysis. This reaction on the name of its discoverer is known as Hill reaction

#### Hill reaction proves that

- (1) In photosynthesis oxygen is released from water.
- (2) Electrons for the reduction of  $CO_2$  are obtained from water [i.e., a reduced substance (hydrogen donor) is produced which later reduces  $CO_2$ ].

Dichlorophenol indophenol is the dye used by Hill for his famous Hill reaction.

According to Arnon (1961), in this process light energy is converted to chemical energy. This energy is stored in ATP (this process of ATP formation in chloroplasts is known as photophosphorylation) and from electron acceptor  $NADP^+$ , a substance found in all living beings  $NADP^+H$  is formed as hydrogen donor. Formation of hydrogen donor  $NADPH$  from electron acceptor  $NADP^+$  is known as photoreduction or production of reducing power  $NADPH$ .

#### Light phase can be explained under the following headings :

(1) **Transfer of energy :** When photon of light energy falls on chlorophyll molecule, one of the electrons pair from ground or singlet state passes into higher energy level called excited singlet state. It comes back to hole of chlorophyll molecule within  $10^{-9}$  seconds.

This light energy absorbed by chlorophyll molecule before coming back to ground state appears as radiation energy, while that coming back from excited singlet state is called fluorescence and is temperature independent. Sometimes the electron at excited singlet state gets its spin reversed because two electrons at the same energy level cannot stay; for sometime it fails to return to its partner electron. As a result it gets trapped at a high energy level.

Due to little loss of energy, it stays at comparatively lower energy level (Triplet state) from excited singlet state. Now at this moment, it can change its spin and from this triplet state, it comes back to ground state again losing excess of energy in the form of radiation. This type of loss of energy is called as phosphorescence.

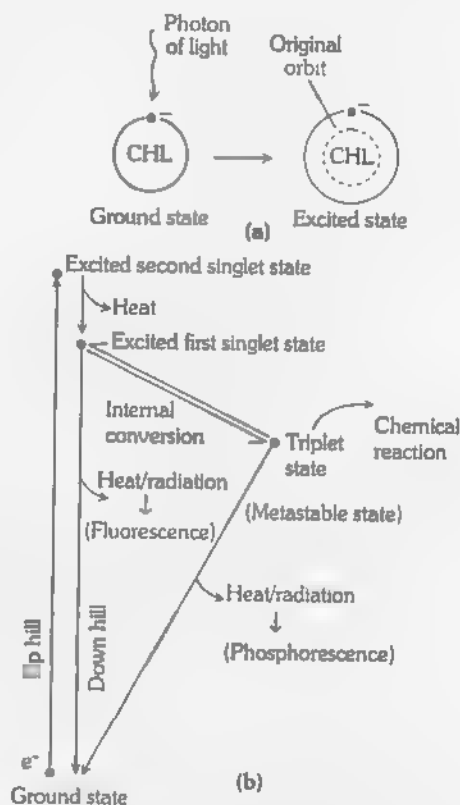


Fig : 4.3-2 (a) Photoexcitation of chlorophyll molecule i.e., of its atoms (b) Movement of electron due to photoexcitation of pigment molecule

When electron is raised to higher energy level, it is called at second singlet state. It can lose its energy in the form of heat also. Migration of electron from excited singlet state to ground state along with the release of excess energy into radiation energy is of no importance to this process. Somehow when this excess energy is converted to chemical energy, it plays a definite constructive role in the process.

#### (2) Quantum yield

(i) Rate or yield of photosynthesis is measured in terms of quantum yield or  $O_2$  evolution, which may be defined as, "Number of  $O_2$  molecules evolved per quantum of light absorbed in photosynthesis."

(ii) Quantum requirement in photosynthesis = 8, i.e., 8 quanta of light are required to evolve one mol. of  $O_2$ .

(iii) Hence quantum yield =  $1 / 8 = 0.125$  (i.e., a fraction of 1) as 12%.

(3) **Emerson effect and Red drop :** R. Emerson and C.M. Lewis (1943) observed that the quantum yield of photosynthesis decreases towards the far red end of the

spectrum (680nm or longer). Quantum yield is the number of oxygen molecules evolved per light quantum absorbed. Since this decrease in quantum yield is observed at the far region or beyond red region of spectrum is called red drop.

Emerson *et al.* (1957) further observed that photosynthetic efficiency of light of 680nm or longer is increased if light of shorter wavelengths (Less than 680nm) is supplied simultaneously. When both short and long wavelengths were given together the quantum-yield of photosynthesis was greater than the total effect when both the wavelengths were given separately. This increase in photosynthetic efficiency (or quantum yield) is known as Emerson effect or Emerson enhancement effect.

$$E = \frac{\text{Quantum yield in combined beam} - \text{Quantum yield in red beam}}{\text{Quantum yield in far red beam}}$$

(4) **Two pigment systems** : The discovery of Emerson effect has clearly shown the existence of two distinct photochemical processes, which are believed to be associated with two different specific group of pigments.

(i) **Pigment system I or Photosystem I** : The important pigments of this system are chlorophyll *a* 670, chlorophyll *a* 683, chlorophyll *a* 695,  $P_{700}$ . Some physiologists also include carotenes and chlorophyll *b* in pigment system I.  $P_{700}$  acts as the reaction centre. Thus, this system absorbs both wavelengths shorter and longer than 680nm.

(ii) **Pigment system II or photosystem II** : The main pigments of this system are chlorophyll *a* 673,  $P_{680}$ , chlorophyll *b* and phycobilins. This pigment system absorbs wavelengths shorter than 680nm only.  $P_{680}$  acts as the reaction centre.

Pigment system I and II are involved in non-cyclic electron transport, while pigment system I is involved only in cyclic electron transport. Photosystem I generates strong reductant NADPH. Photosystem II produces a strong oxidant that forms oxygen from water.

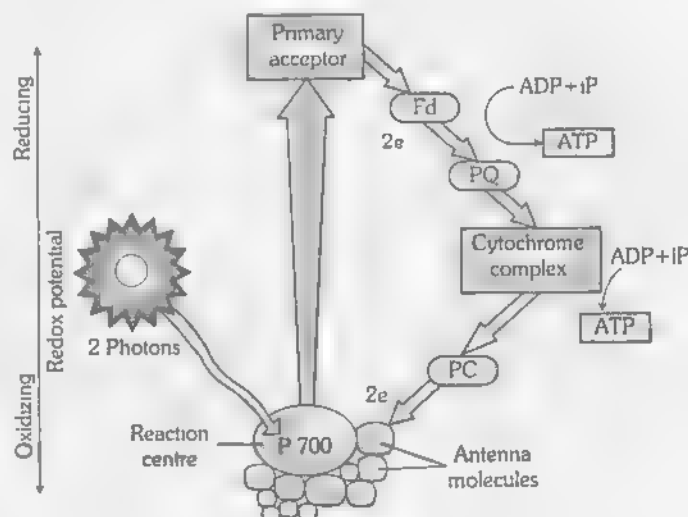
**Table : 4.3-1 Comparison of photosystem I and photosystem II**

S. No.	Photosystem I	Photosystem II
1)	PS I lies on the outer surface of the thylakoids.	PS II lies on the inner surface of the thylakoid.
2)	In this system molecular oxygen is not evolved.	As the result of photolysis of water molecular oxygen is evolved.
3)	Its reaction center is $P_{700}$	Its reaction center is $P_{680}$
4)	It participates both in cyclic and noncyclic photophosphorylation.	It participates only in noncyclic photophosphorylation.
5)	It receives electrons from photosystem II.	It receives electrons from photolytic dissociation of water
6)	It is not related with photolysis of water.	It is related with photolysis of water

(5) **Photophosphorylation** : Light phase includes the interaction of two pigment systems. PS I and PS II constitute various type of pigments. Arnon showed that during light reaction not only reduced NADP is formed and oxygen is evolved but ATP is also formed. This formation of high energy phosphates (ATP) is dependent on light hence called photophosphorylation.

Photophosphorylation is of two types :

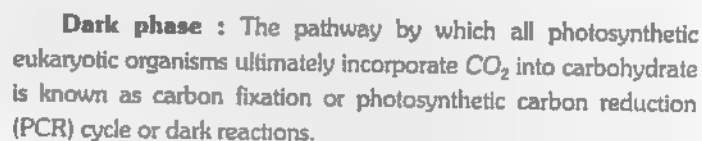
(i) **Cyclic photophosphorylation** : The system is found dominantly in bacteria. It involves only PS I. Flow of electron is cyclic. If NADP is not available then this process will occur. When the photons activate PS I, a pair of electrons are raised to a higher energy level. They are captured by primary acceptor which passes them on to ferredoxin, plastoquinone, cytochrome complex, plastocyanin and finally back to reaction centre of PS I i.e.,  $P_{700}$ . At each step of electron transfer, the electrons lose potential energy. Their trip down hill is caused by the transport chain to pump  $H^+$  across the thylakoid membrane. The proton gradient, thus established is responsible for forming (2 molecules) ATP. No reduction of NADP to  $NADPH + H^+$ . ATP is synthesized at two steps.



**Fig : 4.3-3 Cyclic photophosphorylation**

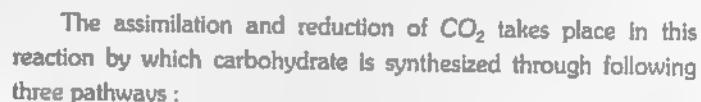
(ii) **Non cyclic photophosphorylation** : The system is dominant in green plants. It involves both PS-I and PS-II. Flow of electrons is unidirectional. Here electrons are not cycled back and are used in the reduction of NADP to  $NADPH_2$ . Here  $H_2O$  is utilized and  $O_2$  evolution occurs. In this chain high energy electrons released from 'P-680' do not return to 'P-680' but pass through pheophytin, plastoquinone, cytochrome  $b_6-f$  complex, plastocyanin (Cu containing pigment) and then enter P-700. In this transfer of electrons from plastoquinone (PQ) to cytochrome  $b_6-f$  complex, ATP is synthesized. Because in this process high energy electrons released from 'P-680' do not return to 'P-680' and ATP (1 molecule) is formed, this is called Noncyclic photophosphorylation. ATP is synthesized at only one step.

Since this process can be continuously self repeated, it appears that a single molecule of water should be sufficient to operate pseudocyclic photophosphorylation to meet the requirement of ATP.

$$\text{FMN} + \text{H}_2\text{O} \xrightleftharpoons[\text{ADP} + \text{P}]{\text{Illuminated chloroplast}} \text{FMNH}_2 + \frac{1}{2} \text{O}_2$$


The dark reactions are sensitive to temperature changes, but are independent of light hence it is called dark reaction, however it depends upon the products of light reaction of photosynthesis, i.e., NADP .2H and ATP

The techniques used for studying different steps were Radioactive tracer technique using  $^{14}\text{C}$  (Half life - 5720 years), Chromatography and Autoradiography and the material used was *Chlorella* (Cloacal alga) and *Scenedesmus* (these are microscopic, unicellular algae and can be easily maintained in laboratory).



(1) **Calvin cycle** : Calvin and Benson discovered the path of carbon in this process. This is known as  $C_3$  cycle because  $CO_2$  reduction is cyclic process and first stable product in this cycle is a 3-C compound (i.e., 3-Phosphoglyceric acid or 3-PGA).

Calvin cycle is divided into three distinct phases  
Carboxylation, Glycolytic reversal, regeneration of RuBP.

As calvin cycle takes in only one carbon (as  $\text{CO}_2$ ) at a time, so it takes six turns of the cycle to produce a net gain of six carbons (i.e., hexose or glucose).

In this cycle, for formation of one mole of hexose sugar (Glucose), 18 ATP and 12 NADPH<sub>2</sub> are used.

The plants in which this pathway of  $\text{CO}_2$  reduction occurs, are called C-3 plants.

About 85% of plant species are C-3 plants, including cereals (e.g., barley, rice, oat, wheat), groundnut, sugarbeet, cotton, tobacco, spinach, soybean most trees and lawn grasses etc.

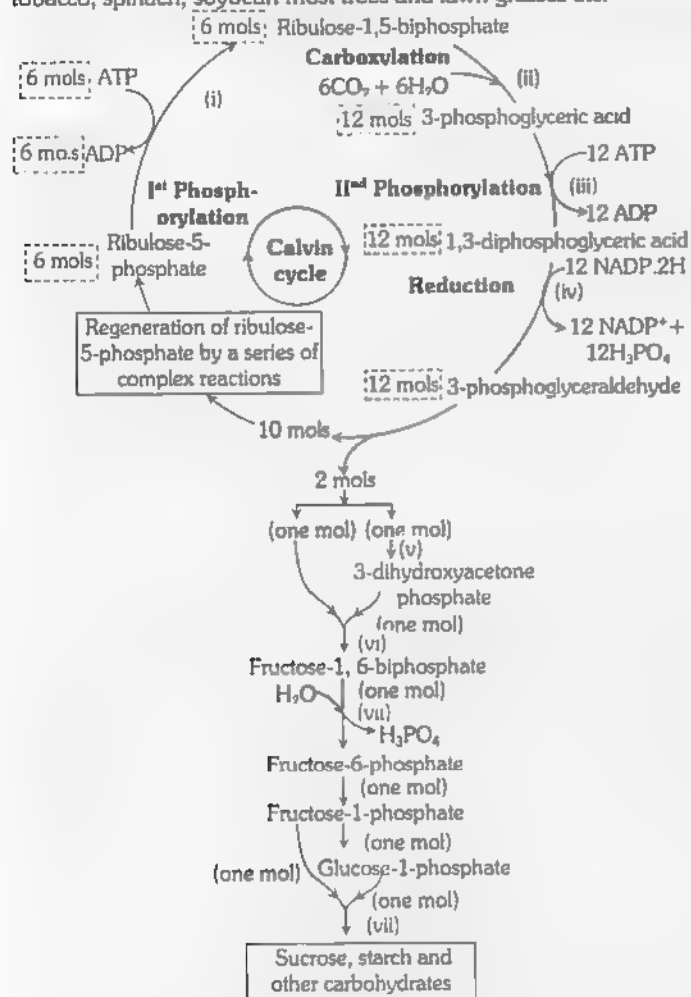


Fig : 4.3-6 Simplified diagram of Calvin cycle

Enzyme : (i) Phosphopentokinase, (ii) Carboxydismutase, (iii) Phosphoglyceric kinase, (iv) Triose phosphate dehydrogenase, (v) Phosphotriose isomerase, (vi) Aldolase, (vii) Phosphatase

(2) **Hatch and Slack cycle (C<sub>4</sub> cycle)** : Kortschak and Hart supplied CO<sub>2</sub> to the leaves of sugarcane, they found that the first stable product is a four carbon (C<sub>4</sub>) compound oxalo acetic acid instead of 3-carbon atom compound. The detailed study of this cycle has introduced by M.D. Hatch and C.R. Slack (1966). So it is called as "Hatch and Slack cycle". The stable product in C<sub>4</sub> plant is a dicarboxylic substance. Hence it is called dicarboxylic acid cycle or DCA-cycle. C<sub>4</sub> plants are true xerophytic plants. They are adapted for hot and dry climate.

The important C<sub>4</sub> plants are sugarcane, maize, Sorghum, *Cyperus rotundus*, *Digitaria brownii*, *Amaranthus*, etc. These plants have "Kranz" (German term meaning halo or wreath) type of leaf anatomy. The vascular bundles, in C<sub>4</sub> leaves are surrounded by a layer of bundle sheath cells that contain large number of chloroplasts. The chloroplasts in C<sub>4</sub> leaves are dimorphic (Two morphologically distinct types). The chloroplasts of bundle sheath cells are larger in size and arranged centripetally. They contain starch grains but lack grana. The mesophyll cells, on the other

hand, contain normal types of chloroplasts. Mesophyll and bundle sheath cells are connected by plasmodesmata. The mesophyll cells perform C<sub>4</sub> cycle and the cells of bundle sheath perform C<sub>3</sub> cycle.

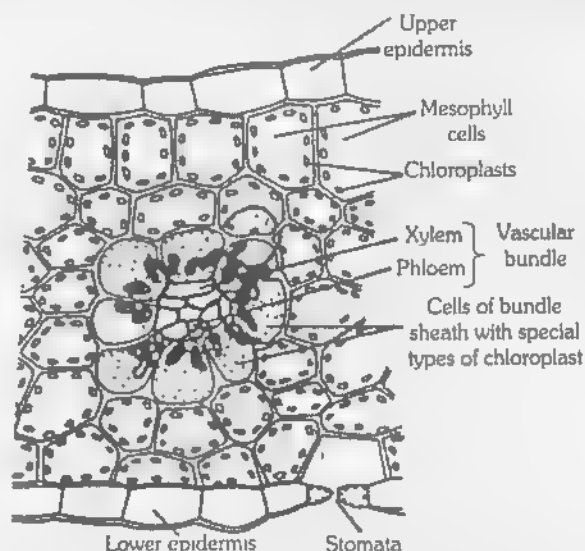


Fig : 4.3-7 Cross section of leaf showing "Kranz" type of anatomy

CO<sub>2</sub> taken from the atmosphere is accepted by phosphoenolpyruvic acid (PEP) present in the chloroplasts of mesophyll cells of these leaves, leading to the formation of a 4-C compound, oxaloacetic acid (OAA). This acid is converted to another 4-C acid, the malic acid which enters into the chloroplasts of bundle sheath cells and there undergoes oxidative decarboxylation yielding pyruvic acid (a 3-C compound) and CO<sub>2</sub>. CO<sub>2</sub> released in bundle sheath cells reacts with Ribulose-1,5-bisphosphate (RuBP) already present in the chloroplasts of bundle sheath cells and thus Calvin cycle starts from here. Pyruvic acid re-enters mesophyll cells and regenerates phosphoenol pyruvic acid. CO<sub>2</sub> after reacting with RuBP gives rise to sugars and other carbohydrates. In C<sub>4</sub> plants, there are 2 carboxylation reactions, first in mesophyll chloroplast and second in bundle sheath chloroplast.

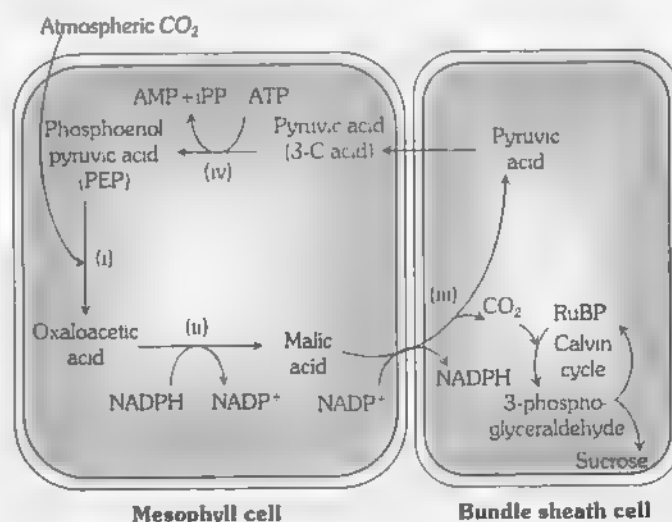


Fig : 4.3-8 Hatch-slack's pathway (cycle) Enzymes : (i) Phosphoenol pyruvate carboxylase, (ii) Malate dehydrogenase, (iii) Decarboxylase, (iv) Pyruvate orthophosphate dikinase



$C_4$  plants are better photosynthesizers. There is no photorespiration in these plants. In  $C_4$  plants, for formation of one molecule of hexose (glucose) 30 ATP and 12  $NADPH_2$  are required.

### Characteristics of C<sub>4</sub> cycle

(1)  $C_4$  species have greater rate of  $CO_2$  assimilation than  $C_3$  species. This is on account of the fact that

(i) PEP carboxylase has great affinity for  $\text{CO}_2$ .

(ii)  $C_4$  plants show little photorespiration as compared to  $C_3$  plants, resulting in higher production of dry matter.

(2)  $C_4$  plants are more adapted to environmental stresses than  $C_3$  plants.

(3)  $\text{CO}_2$  fixation by  $\text{C}_4$  plants requires more ATP than that by  $\text{C}_3$  plants. This additional ATP is needed for conversion of pyruvic acid to phosphoenol pyruvic acid and its transport.

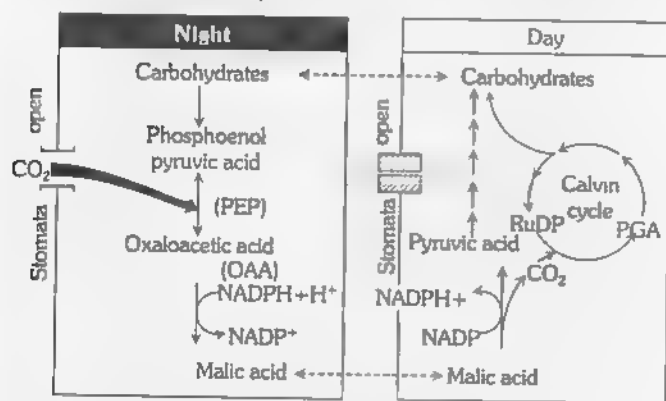
(4)  $\text{CO}_2$  acceptor molecule in  $\text{C}_4$  plants is PEP. Further, PEP-carboxylase (PEPCO) is the key enzyme (RuBP-carboxylase enzyme is negligible or absent in mesophyll chloroplast, but is present in bundle sheath chloroplast).

(3) **Crassulacean acid metabolism (CAM)** : This dark  $\text{CO}_2$  fixation pathway proposed by Ting (1971). It operates in succulent or fleshy plants e.g., *Cactus*, *Sedum*, *Kalanchoe*, *Opuntia*, *Agave*, *Orchid*, *Pineapple* and *Bryophyllum* helping them to continue photosynthesis under extremely dry condition.

The stomata of succulent plants remain closed during day and open during night to avoid water loss (Scotoactive stomata). They store  $\text{CO}_2$  during night in the form of malic acid in presence of enzyme PEP carboxylase. The  $\text{CO}_2$  stored during night is used in Calvin cycle during day time. Succulents refix  $\text{CO}_2$  released during respiration and use it during photosynthesis.

This diurnal change in acidity was first discovered in crassulacean plants e.g., *Bryophyllum*. So it is called as crassulacean acid metabolism.

Formation of malic acid during dark is called acidification or phase-I. Release of  $\text{CO}_2$  for actual photosynthesis during day is called deacidification or phase-II.



**Fig : 4.3-9 Mechanism of CAM**

### Characteristics of CAM pathway

(1) There is decrease in  $pH$  during the night and increase in  $pH$  during the day.

(2) CAM plants have enzymes of both  $C_3$  and  $C_4$  cycle in mesophyll cells. This metabolism enable CAM plants to survive under xeric habitats. These plants have also the capability of fixing the  $CO_2$  lost in respiration.

(3) Malic acid is stored in the vacuoles during the night which is decarboxylated to release  $\text{CO}_2$  during the day.

### CO<sub>2</sub> compensation point

In photosynthesis,  $\text{CO}_2$  is utilized in presence of light to release  $\text{O}_2$  whereas in respiration,  $\text{O}_2$  is taken and  $\text{CO}_2$  is released. If light factor is saturating, there will be certain  $\text{CO}_2$  concentration at which rate of photosynthesis is just equal to rate of respiration or photosynthesis just compensates respiration or apparent photosynthesis is nil. It is called  $\text{CO}_2$  compensation point.

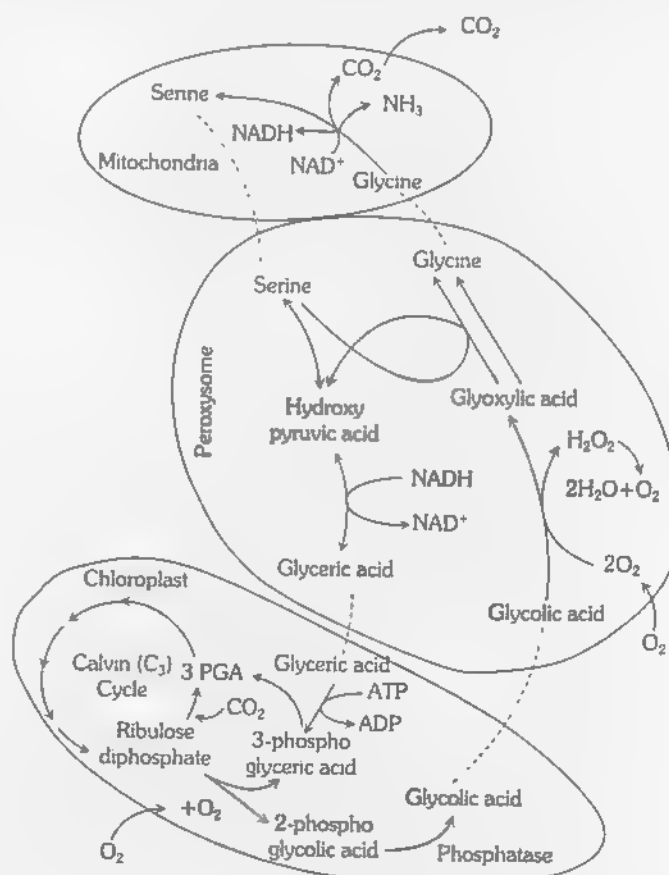
□  $\text{CO}_2$  compensation point is very low in  $\text{C}_4$  plants, i.e. 0 to 5 ppm whereas high  $\text{CO}_2$  compensation point is found in  $\text{C}_3$  plants, i.e. 25 to 100 ppm.

### Photorespiration or $\text{CO}_2$ Cycle

Decker and Tio (1959) reported that light induces oxidation of photosynthetic intermediates with the help of oxygen in tobacco. It is called as photorespiration. The photorespiration is defined by Krotkov (1963) as an extra input of  $O_2$  and extra release of  $CO_2$  by green plants is light.

Photorespiration is the uptake of  $O_2$  and release of  $CO_2$  in light and results from the biosynthesis of glycolate in chloroplasts and subsequent metabolism of glycolate acid in the same leaf cell. Biochemical mechanism for photorespiration is also called glycolate metabolism.

Loss of energy occurs during this process. The process of photorespiration involves the involvement of chloroplasts, peroxysomes and mitochondria. RuBP carboxylase also catalyses another reaction which interferes with the successful functioning of Calvin cycle.



**Fig : 4.3-10 The biochemical pathway of photorespiration**

**Biochemical mechanism**

- (1) Ribulose-1, 5-bisphosphate  $\xrightarrow{O_2}$   
2 Phosphoglycolic acid + 3 Phosphoglyceric acid
- (2) 2 Phosphoglycolic acid +  $H_2O \xrightarrow{\text{Phosphatase}}$   
Glycolic acid + Phosphoric acid
- (3) Glycolic acid +  $O_2 \xrightarrow[\text{oxidase}]{\text{Glycolic acid}}$  Glyoxylic acid +  $H_2O_2$   
 $2H_2O_2 \xrightarrow{\text{Catalase}} 2H_2O + O_2$
- (4) Glyoxylic acid + Glutamic acid  $\xrightarrow[\text{transaminase}]{\text{Glutamate-glyoxylate}}$   
Glycine +  $\alpha$ -keto glutaric acid
- (5) 2 Glycine +  $H_2O + NAD^+ \longrightarrow$   
Serine +  $CO_2 + NH_3 + NADH$
- (6) Serine + Glyoxylic acid  $\longrightarrow$  Hydroxypyruvic acid  
Glycine + Hydroxypyruvic acid  $\longrightarrow$  Glyceric acid
- (7) Glyceric acid + ATP  $\rightarrow$  3 phosphoglyceric acid  
+ ADP + phosphate

**Importance of photorespiration :** Photorespiration is quite different from respiration as no ATP or NADH are produced. Moreover, the process is harmful to plants because as much as half the photosynthetically fixed carbon dioxide (in the form of RuBP) may be lost into the atmosphere through this process.

Any increase in  $O_2$  concentration would favour the uptake of  $O_2$  rather than  $CO_2$  and thus, inhibit photosynthesis for this rubisco functions as RuBP oxygenase. Photorespiration is closely related to  $CO_2$  compensation point and occurs only in those plants which have high  $CO_2$  compensation point such as  $C_3$  plants.

Photorespiration generally occurs in temperate plants. Few photorespiring plants are : Rice, bean, wheat, barley etc. Inhibitors of glycolic acid oxidase such as hydroxy sulphonates inhibit the process of photorespiration. Unlike usual mitochondria respiration neither reduced coenzymes are generated in photorespiration nor the oxidation of glycolate is coupled with the formation of ATP molecules. Photorespiration ( $C_2$  cycle) is enhanced by bright light, high temperature, high oxygen and low  $CO_2$  concentration.

**Bacterial photosynthesis**

Like green plants, some purple and green sulphur bacteria are capable of synthesizing their organic food in presence of light and in absence of  $O_2$ , which is known as bacterial photosynthesis.

Van Niel was the first to point out these similarities. Oxygen is not liberated in bacteria during process of photosynthesis. Their photosynthesis is non-oxygenic. Because bacteria use  $H_2S$  in place of water ( $H_2O$ ) as hydrogen donor. Photosynthetic bacteria are anaerobic. Only one type of pigment system (PSI) is found in bacteria except cyanobacteria which possess both PSI and PSII.

Bacteria has two type of photosynthetic pigments. Bacteriochlorophyll and Bacterioviridin. Bacteriochlorophyll differs from Chl. *a* in having one pyrrol ring with two hydrogen.

**The photosynthetic bacteria fall under three categories**

(1) **Green sulphur bacteria :** It contains chlorobium chlorophyll, which absorb 720-750nm (far red light) of wavelength of light. e.g., *Chlorobium*.

(2) **Purple sulphur bacteria :** e.g., *Chromatium*.

(3) **Purple non-sulphur bacteria :** e.g., *Rhodospirillum*, *Rhodopseudomonas*.

Characteristics of bacterial photosynthesis are :

- (1) No definite chloroplasts but contain simple structures having pigments called chromatophores (term coined by Schmitz).
- (2) Contain chlorobium chlorophyll or bacterio-chlorophyll.
- (3) Use longer wavelengths of light (720-950nm).
- (4) No utilization of  $H_2O$  (but use  $H_2S$  or other reduced organic and inorganic substances).
- (5) No evolution of  $O_2$ .
- (6) Photoreductant is  $NADH_2$  (Not  $NADPH_2$ ).
- (7) Only one photoact and hence one pigment system and thus one reaction centre, i.e.,  $P_{890}$ .
- (8) Cyclic photophosphorylation is dominant.
- (9) It occurs in presence of light and in absence of  $O_2$ .

**Chemosynthesis**

Some forms of bacteria obtain energy by chemosynthesis. This process of carbohydrate formation in which organisms use chemical reactions to obtain energy from inorganic compounds is called chemosynthesis. Such chemoautotrophic bacteria do not require light and synthesize all organic cell requirements from  $CO_2$  and  $H_2O$  and salts at the expense of oxidation of inorganic substances like ( $H_2$ ,  $NO_3^-$ ,  $SO_4$  or carbonate). Some examples of chemosynthesis are :

(1) **Nitrifying bacteria :** e.g., *Nitrosomonas*, *Nitrosococcus*, *Nitrobacter* etc.

(2) **Sulphur bacteria :** e.g., *Beggiatoa*, *Thiothrix* and *Thiobacillus*.

(3) **Iron bacteria :** e.g., *Ferrobacillus*, *Leptothrix* and *Cladothrix*.

(4) **Hydrogen bacteria :** e.g., *Bacillus pentotrophus*

(5) **Carbon bacteria :** e.g., *Carboxydomonas*, *Bacillus oligocarbophilus*

## Factors affecting photosynthesis

### Blackman's law of limiting factors

F.F. Blackman (1905) proposed the law of limiting factors according to which 'when process is conditioned to its rapidity by a number of factors, the rate of process is limited by the pace of the slowest factor'.  $\text{CO}_2$  is usually a limiting factor in photosynthesis under field conditions particularly on clear summer days under adequate water supply.

Blackman's law of limiting factor is modification of Liebig's law of minimum, which states that rate of process controlled by several factors is only as rapid as the slowest factor permits. Theory of three cardinal points was given by Sachs in 1860. According to this concept, there is minimum, optimum and maximum for each factor. For every factor, there is a minimum value when photosynthesis starts, an optimum value showing highest rate and a maximum value, above which photosynthesis fails to take place.

**Factors :** The rate of photosynthetic process is affected by several external (Environmental) and internal factors.

### External factors

(1) **Light :** The ultimate source of light for photosynthesis in green plants is solar radiation, which moves in the form of electromagnetic waves. Out of the total solar energy reaching to the earth about 2% is used in photosynthesis and about 10% is used in other metabolic activities. Light varies in intensity, quality (Wavelength) and duration. The effect of light on photosynthesis can be studied under these three headings.

(i) **Light intensity :** The total light perceived by a plant depends on its general form (viz., height, size of leaves, etc.) and arrangement of leaves. Of the total light falling on a leaf, about 80% is absorbed, 10% is reflected and 10% is transmitted.

In general, rate of photosynthesis is more in intense light than diffused light. (Upto 10% light is utilized in sugarcane, i.e., Most efficient converter).

Another photosynthetic superstar of field growing plants is *Oenothera lutea* (Winter evening-primrose), which utilizes about 8% light.

However, this light intensity varies from plant to plant, e.g., more in heliophytes (sun loving plants) and less in sciophytes (shade loving plants). For a complete plant, rate of photosynthesis increases with increase in light intensity, except very high light intensity where 'Solarization' phenomenon occurs, i.e., photo-oxidation of different cellular components including chlorophyll occurs.

It also affects the opening and closing of stomata thereby affecting the gaseous exchange. The value of light saturation at which further increase is not accompanied by an increase in  $\text{CO}_2$  uptake is called light saturation point.

(ii) **Light quality :** Photosynthetic pigments absorb visible part of the radiation i.e., 380m $\mu$  to 760m $\mu$ . For example, chlorophyll absorbs blue and red light. Usually plants show high rate of photosynthesis in the blue and red light. Maximum photosynthesis has been observed in red light than in blue light. The green light has minimum effect. On the other hand, red algae shows maximum photosynthesis in green light and brown algae in blue light.

(iii) **Duration of light :** Longer duration of light period favours photosynthesis. Generally, if the plants get 10 to 12hrs light per day it favours good photosynthesis. Plants can actively exhibit photosynthesis under continuous light without being damaged. Rate of photosynthesis is independent of duration of light.

(2) **Temperature :** The optimum temperature for photosynthesis is 20 to 35°C. If the temperature is increased too high, the rate of photosynthesis is also reduced by time factor which is due to denaturation of enzymes involved in the process. Photosynthesis occurs in some conifers at high altitudes at -35°C. Some algae in hot springs can undergo photosynthesis even at 75°C.

(3) **Carbon dioxide :** Carbon dioxide present in the atmosphere is about 0.032% by volume and it is really a low concentration which acts as limiting factor in nature. If we increase the amount of  $\text{CO}_2$  under laboratory conditions and if the light and temperature are not the limiting factors, the rate of photosynthesis increases. This increase is observed upto 1% of  $\text{CO}_2$  concentration. At the same time very high concentration of  $\text{CO}_2$  becomes toxic to plants and inhibits photosynthesis.

(4) **Water :** Water is an essential raw material in photosynthesis. This rarely, acts as a limiting factor because less than 1% of the water absorbed by a plant is used in photosynthesis. However, lowering of photosynthesis has been observed if the plants are inadequately supplied with water.

(5) **Oxygen :** Excess of  $\text{O}_2$  may become inhibitory for the process. Enhanced supply of  $\text{O}_2$  increases the rate of respiration simultaneously decreasing the rate of photosynthesis by the common intermediate substances. The concentration for oxygen in the atmosphere is about 21% by volume and it seldom fluctuates.  $\text{O}_2$  is not a limiting factor of photosynthesis. An increase in oxygen concentration decreases photosynthesis and the phenomenon is called Warburg effect. (Reported by German scientist Warburg (1920) in *Chlorella* algae).

This is due to competitive inhibition of RuBP-carboxylase by increased  $\text{O}_2$  levels, i.e.,  $\text{O}_2$  competes for active sites of RuBP-carboxylase enzyme with  $\text{CO}_2$ . The explanation of this problem lies in the phenomenon of photorespiration. If the amount of oxygen in the atmosphere decreases then photosynthesis will increase in  $\text{C}_3$  cycle and no change in  $\text{C}_4$  cycle.

(6) **Pollutants and Inhibitors :** The oxides of nitrogen and hydrocarbons present in smoke react to form peroxyacetyl nitrate (PAN) and ozone. PAN is known to inhibit Hill reaction. Diquat and Paraquat (Commonly called as Viologens) block the transfer of electrons between Q and PQ in PS. II. Other inhibitors of photosynthesis are monuron or CMU (Chlorophenyl dimethyl urea) diuron or DCMU (Dichlorophenyl dimethyl urea), bromocil and atrazine etc. Which have the same mechanism of action as that of viologens.

At low light intensities potassium cyanide appears to have no inhibiting effect on photosynthesis.

(7) **Minerals :** Presence of  $\text{Mn}^{++}$  and  $\text{Cl}^-$  is essential for smooth operation of light reactions (Photolysis of water/evolution of oxygen)  $\text{Mg}^{++}$ ,  $\text{Cu}^{++}$  and  $\text{Fe}^{++}$  ions are important for synthesis of chlorophyll.

### Internal factors

(1) **Protoplasmic factors :** There is some unknown factor which affects the rate of photosynthesis.

These factors affect the dark reactions. The decline in the rate of photosynthesis at temperature above 30°C or at strong light intensities in many plants suggests the enzymatic nature of this unknown factor.

(2) **Chlorophyll content** : Chlorophyll is an essential internal factor for photosynthesis. The amount of  $\text{CO}_2$  fixed by a gram of chlorophyll in an hour is called photosynthetic number or assimilation number. It is usually constant for a plant species but rarely it varies. The assimilation number of variegated variety of a species was found to be higher than the green leaves variety.

(3) **Accumulation of end products** : Accumulation of food in the chloroplasts reduces the rate of photosynthesis.

(4) **Structure of leaves** : The amount of  $\text{CO}_2$  that reaches the chloroplast depends on structural features of the leaves like the size, position and behaviour of the stomata and the amount of intercellular spaces. Some other characters like thickness of cuticle, epidermis, presence of epidermal hairs, amount of mesophyll tissue, etc., influence the intensity and quality of light reaching in the chloroplast.

## Tips & Tricks

✍ Photosynthetic materials : 264 gm of  $\text{CO}_2$  and 216 gm of water give rise to 108 gm of water, 192 gm of  $\text{O}_2$  and 180 gm of glucose.

✍ Rubisco : Rubisco constitutes 16% of chloroplast protein. It is the most abundant protein on this planet.

✍ Willmott's bubbler is used to measure rate of  $\text{O}_2$  evolution or rate of photosynthesis.

✍ T.W. Engelmann (1882) experimentally verified that in monochromatic lights, photosynthesis is maximum in red light.

✍ NADP (Nicotinamide adenine dinucleotide phosphate) was earlier called as TPN (Triphosphopyridine nucleotide),

✍ In green plants the hydrogen acceptor is NADP, but in bacteria it is NAD.

✍ No Emerson effect is seen in bacteria.

✍ Cytochromes : The terms was coined by Keilin (1925) though the biochemicals were discovered by Mac Munn (1866).

✍ Cytochrome proteins serving as electron carriers in respiration, photosynthesis and other oxidative reduction reactions.

✍ Intensity of light can be measured by Luxmeter.

✍ Isolated chlorophyll 'a' in pure form emits red colour. It is called fluorescence.

✍ In angiosperms, synthesis of chlorophyll occurs in presence of light.

✍ The precursor of chlorophyll is chlorophyllide.

✍ Chlorophyll term was coined by Pelletier and Coventou (1818) who also discovered the pigment.

✍ *Hydrilla* plant is used in an experiment commonly performed in laboratory in demonstrate evolution of  $\text{O}_2$  in photosynthesis.

## Ordinary Thinking

### Objective Questions

#### History of photosynthesis

- The law of limiting factor for photosynthesis was enunciated by [NCERT; CMC Vellore 1994; CBSE PMT 1996; CPMT 2001; Manipal 2001, 05; KCET 2004; BHU 2006]
 

(a) Blackman	(b) Hill
(c) Ruben	(d) Kalmen
- Who proposed the CAM pathway of  $\text{CO}_2$  fixation
 

(a) Benson and associates	(b) Rouhani and associates
(c) Hatch and associates	(d) Arnon and associates
- Two pigment system theory of photosynthesis was proposed by or Concept of evidence for existence of two photosystems in photosynthesis was given by [CBSE PMT 1994; Kerala CET 2003; KCET 2003]
 

(a) Hill	(b) Blackman
(c) Emerson	(d) Arnon
- Who received the Nobel Prize for working out the early carbon pathway of photosynthesis [AIEEE Pharmacy 2003]
 

(a) Calvin	(b) Krebs
(c) Khorana	(d) Watson
- Which of the following technique was used by Calvin in determining carbon pathway [MP PMT 1992]
 

(a) Chromatography	(b) Electrophoresis
(c) Spectrophotometry	(d) Histochemistry
- The process of photophosphorylation was discovered by [Pb. PMT 1999, 2000]
 

(a) Calvin	(b) Arnon
(c) Priestley	(d) Warburg
- Most of the plants contain a green colouring pigment which is responsible for photosynthesis. This pigment was named chlorophyll by
 

(a) Melvin Calvin	(b) Jean Senebier
(c) Julius Robert Mayer	(d) Pelletier Coventou
- 'Photosynthesis is the conversion of light energy within a plant' was first stated by
 

(a) Willstatter and Stoll	(b) Mayor and Anderson
(c) Benson and Calvin	(d) Robert Mayer
- 'Thylakoid' name was given by [RPMT 1995]
 

(a) Arnon	(b) Park and Biggins
(c) Park and Fortan	(d) Manke
- The significance of light and chlorophyll in photosynthesis was discovered by [Bihar MDAT 1995]
 

(a) Priestley	(b) Ingenhousz
(c) Englemann	(d) Blackman
- "The amount of  $\text{CO}_2$  absorbed and  $\text{O}_2$  released during photosynthesis are in equal volumes" was proved by
 

(a) Englemann	(b) Robert Mayer
(c) Priestley	(d) Bousingault

12. The first important biological investigation which led to the conclusion that plant makes its substance from water and not from soil was carried out by
  - (a) Lamarck (b) De Vries
  - (c) Van Helmont (d) Darwin
13. Early studies on the pathway of  $\text{CO}_2$  fixation in plants were made during 1940s in
  - (a) Unicellular green algae by Calvin
  - (b) Isolated chloroplast of spinach by Hill
  - (c) Mesophyll cells of variegated leaves by Arnon
  - (d) Bundle sheath cells of maize by Hatch and Slack
14. Who proposed the cycle of events leading to the fixation of  $\text{CO}_2$  in mesophyll and its reduction in bundle sheath
  - (a) Emerson (b) Melvin Calvin
  - (c) Hatch and Slack (d) Hill and Bendall
15. The scientist, who proved that bacteria use  $\text{H}_2\text{S}$  gas and  $\text{CO}_2$  to synthesize carbohydrate, is [NCERT]
  - (a) Van Niel (b) Ruben
  - (c) Jean Senebier (d) Julius Robert Mayer
16. Emerson's enhancement effect and Red drop have been instrumental in the discovery of [NEET (Phase-I) 2016]
  - (a) Photophosphorylation and non-cyclic electron transport
  - (b) Two photosystems operating simultaneously
  - (c) Photophosphorylation and cyclic electron transport
  - (d) Oxidative phosphorylation

### Experiments

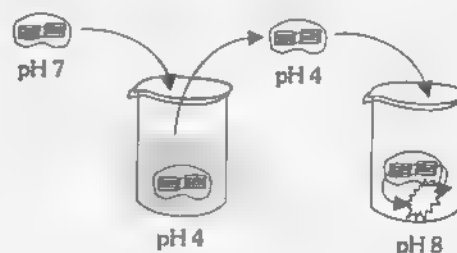
1. What plant is used in an experiment commonly performed in laboratory to demonstrate evolution of oxygen in photosynthesis [RPMT 1997]
  - (a) Sunflower (b) Hydrilla
  - (c) Croton (d) Balsam
2. Engelmann's experiment with *Spirogyra* demonstrated that [BVP 2003]
  - (a) The full spectrum of sunlight is needed for photosynthesis
  - (b) Only red wavelengths are effective in causing photosynthesis
  - (c) Only blue wavelengths are effective
  - (d) Both blue and red wavelengths are effective
3. Two plants A and B are supplied with  $\text{CO}_2$  with  $\text{H}_2\text{O}^{18}$  and  $\text{CO}_2^{18}$  with  $\text{H}_2\text{O}$  respectively which of the following plant releases  $\text{O}^{18}$  type oxygen in photosynthesis [CPMT 2000]
  - (a) A plant (b) B plant
  - (c) Both (a) and (b) (d) First (a) and then (b)
4. Isotopes popularly known to have been used in the study of photosynthesis are [MH CET 2007]
 

Or

Which of the following isotope of carbon was used by Calvin to trace the path of carbon in photosynthesis [CPMT 1995]

- (a)  $\text{C}^{14}$  and  $\text{O}^{18}$  (b)  $\text{C}^{11}$  and  $\text{C}^{32}$
- (c)  $\text{C}^{16}$  and  $\text{N}^{15}$  (d)  $\text{P}^{32}$  and  $\text{C}^{15}$

5. The given diagram represents an experiment with isolated chloroplasts. The chloroplasts were first made acidic by soaking them in a solution at pH 4. After the thylakoid space reached pH 4, the chloroplast were transferred to a basic solution at pH 8. The chloroplasts are then placed in the dark. Which of these compounds would you expect to be produced [NCERT]



- (a)  $\text{C}_6\text{H}_{12}\text{O}_6$  (b) G3P
- (c) NAD (d) ATP
6. Path of carbon in photosynthesis was found by using [Kerala CET 2002]
  - (a) Centrifugation (b) Radio isotopes
  - (c) Fractionation (d) Chromatography
7. Persons who received Nobel Prizes for their work with green plants are
  - (a) Calvin and Waston (b) Calvin and Borlang
  - (c) Beadle and Tatum (d) Flemming and Waksman
8. Which of the following with respect to early experiments of photosynthesis is wrongly matched [Kerala PMT 2012]
  - (a) Joseph Priestley – Showed that plants release  $\text{O}_2$
  - (b) Jan Ingenhousz – Showed that sunlight is essential for photosynthesis
  - (c) Julius von Sachs – Proved that plants produce glucose when they grow
  - (d) T.W. Engelmann – Showed that the green substance is located within special bodies in plant
  - (e) Cornelius van Net – Showed that hydrogen reduces  $\text{CO}_2$  to carbohydrates
9. The path of  $\text{CO}_2$  in the dark reaction of photosynthesis was successfully traced by the use of the following or The dark reaction is traced by [BHU 1992]
  - (a)  $\text{O}_2^{18}$  (b)  $\text{C}^{14}\text{O}_2$
  - (c)  $\text{P}^{36}$  (d) X-rays
10. Algae used by Calvin and associates for photosynthetic research is [RPMT 2002]

Or

The experimental material that has largely been responsible for making rapid advances in research on photosynthesis is

[RPMT 2002]

Or

Warburg studied his effect on

- (a) *Chlorella* (b) *Chlamydomonas*
- (c) *Volvox* (d) All the above

11. The oxygen produced during photosynthesis comes from photolysis of water was first time proved by [MP PMT 1995]  
(a) Ruben and Kamen (b) Robert Mayer  
(c) Malvin Calvin (d) Blackman
12. The first experiment on photosynthesis in flashing light were carried out by [AFMC 2006]  
(a) F. F. Blackman  
(b) Robert Emerson and Arnold  
(c) Melvin Calvin  
(d) Robert Hill
13. Moll's experiment shows [KCET 2001]  
(a) Unequal transpiration from two surfaces of leaf  
(b) Relation between transpiration and absorption  
(c)  $\text{CO}_2$  is required for photosynthesis  
(d) Chlorophyll is essential for photosynthesis

### Photosynthetic apparatus

1. The plants growing in dark show yellowing in leaves and elongated internodes, this condition is called as [BHU 1999]  
(a) Etiolation (b) Chlorosis  
(c) Dechlorosis (d) Dark effect
2. The most vital process for the existence of life on earth is [KCET 1994]  
(a) Communication in animals  
(b) Photosynthesis by plants  
(c) Reproduction in plants and animals  
(d) Respiration in animals
3. Match the following and choose the correct combination from the options given
- | Column - I |               | Column - II |                    |
|------------|---------------|-------------|--------------------|
| A.         | Visible light | 1.          | 0.1 to 1 nm        |
| B.         | Ultraviolet   | 2.          | 400 to 700 nm      |
| C.         | X-Rays        | 3.          | Longer than 740 nm |
| D.         | Infrared      | 4.          | 100 to 400 nm      |
|            |               | 5.          | < 0.1 nm           |
- [Kerala PMT 2007]  
(a) A-1, B-3, C-4, D-5 (b) A-3, B-2, C-1, D-5  
(c) A-4, B-3, C-2, D-1 (d) A-2, B-4, C-1, D-3  
(e) A-5, B-4, C-3, D-2
4. How many molecules of water are needed by a green plant to produce one molecule of hexose/ reduce 6 molecules of  $\text{CO}_2$   
(a) 6 (b) 12  
(c) 24 (d) One only
5. The first event in photosynthesis is [JIPMER 2002; CBSE PMT 2000; AIEEE Pharmacy 2004]  
(a) Synthesis of ATP  
(b) Photoexcitation of chlorophyll and ejection of electron  
(c) Photolysis of water  
(d) Release of oxygen
6. Which of the following represents the correct molecular formula of chlorophyll-b [RPMT 2005]  
(a)  $\text{C}_{55}\text{H}_{72}\text{O}_6\text{N}_4\text{Mg}$  (b)  $\text{C}_{55}\text{H}_{72}\text{O}_5\text{N}_4\text{Mg}$   
(c)  $\text{C}_{55}\text{H}_{72}\text{O}_4\text{N}_4\text{Mg}$  (d)  $\text{C}_{55}\text{H}_{70}\text{O}_5\text{N}_4\text{Mg}$   
(e)  $\text{C}_{55}\text{H}_{70}\text{O}_6\text{N}_4\text{Mg}$
7. Solar energy is converted into ATP in  
**Or**  
Light energy is converted into chemical energy in the presence of [MP PMT 1994]  
(a) Mitochondria (b) Chloroplasts  
(c) Ribosomes (d) Peroxisomes
8. Which process is related with photosynthesis [CPMT 1998]  
(a) Phosphorylation (b) Translation  
(c) Transcription (d) None of these
9. Which of the following equation can be more appropriate for photosynthesis [NCERT; KCET 1994; Kerala PMT 2004, 06]  
(a)  $6\text{CO}_2 + 6\text{H}_2\text{O} \xrightarrow[\text{Chlorophyll}]{\text{Light}} \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$   
(b)  $6\text{CO}_2 + 12\text{H}_2\text{O} \xrightarrow[\text{Chlorophyll}]{\text{Light}} \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{H}_2\text{O} + 6\text{O}_2$   
(c)  $12\text{CO}_2 + 6\text{H}_2\text{O} \xrightarrow[\text{Chlorophyll}]{\text{Light}} 2\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$   
(d) None of the above
10. Quantasomes are found in [RPMT 1995]  
(a) Surface of cristae  
(b) Surface of plasma membrane  
(c) Surface of nuclear membrane  
(d) Surface of thylakoids
11. The full expansion of NADP is [RPMT 1997]  
(a) Nicotinamide adenine diphosphate  
(b) Nicotinamide adenosine diphosphate  
(c) Nicotinamide adenine dinucleotide phosphate  
(d) Nicotinamide adenosine dinucleotide phosphate
12. Make suitable pair  
(A) Emerson effect (a)  $\text{C}_4$  cycle  
(B) Hill reaction (b) Photolysis  
(C) Calvin's cycle (c)  $\text{C}_3$  cycle  
(D) Hatch and Slack cycle (d) Photosystem-I and II [RPMT 1997]  
(a) Aa, Bb, Cc, Dd (b) Aa, Bc, Cd, Db  
(c) Ac, Bd, Ca, Db (d) Ad, Bb, Cc, Da
13. Suspension of isolated thylakoids in culture medium containing  $\text{CO}_2$  and  $\text{H}_2\text{O}$  does not produce hexose due to absence of which of the following [DPMT 2004]  
(a) ATP (b) Enzyme  
(c) Proteins (d) Hill reagent

14. Match the sites in column I with the processes in column II and choose the correct combination from the options

Column I		Column II	
A.	Grana of chloroplast	1.	Kreb's cycle
B.	Stroma of chloroplast	2.	Light reaction
C.	Cytoplasm	3.	Dark reaction
D.	Mitochondrial matrix	4.	Glycolysis

[RPMT 1995; MP PMT 2000; Kerala PMT 2004]

- (a) A-4, B-3, C-2, D-1 (b) A-1, B-2, C-4, D-3  
(c) A-2, B-1, C-3, D-4 (d) A-3, B-4, C-1, D-2  
(e) A-2, B-3, C-4, D-1
15. 85-90% of all photosynthesis of the world is carried out by [AMU (Med.) 2009]

Or

The maximum evolution of oxygen is by greatest producers of organic matter

- (a) Shrubs  
(b) Herbs  
(c) Oceanic algae/Phytoplanktons  
(d) Trees with large branches
16. See the following diagram and identify X and Y with their functions [NCERT]



X			Y	
	Structure	Function	Structure	Function
(a)	Grana	CO <sub>2</sub> fixation	Lamellae	Photolysis of water
(b)	Stroma	Photolysis	Grana	CO <sub>2</sub> fixation
(c)	Grana	CO <sub>2</sub> fixation	Stroma	Photolysis of water
(d)	Grana	Photolysis of water	Stroma	CO <sub>2</sub> fixation

17. In photosynthesis, energy from light reaction to dark reaction is transferred in the form of [CBSE PMT 2002]  
(a) ADP (b) ATP  
(c) RUDP (d) Chlorophyll
18. The synthesis of ATP in photosynthesis and respiration is essentially an oxidation-reduction process involving removal of energy from [CBSE PMT 1992; BHU 1994]

Or

Which one is always transferred in redox reaction

[Odisha JEE 2009]

- (a) Oxygen (b) Phytochrome  
(c) Cytochrome (d) Electrons
19. In photosynthesis, plants [AFMC 2003; MP PMT 2004]  
(a) Absorb O<sub>2</sub> and release CO<sub>2</sub>  
(b) Absorb CO<sub>2</sub> and release O<sub>2</sub>  
(c) Absorb NH<sub>3</sub> and release N<sub>2</sub>  
(d) Absorb N<sub>2</sub> and release NH<sub>3</sub>

20. Wavelength of green light is  
(a) 400 - 450 mμ (b) 500 - 550 mμ  
(c) 660 - 720 mμ (d) 720 - 800 mμ
21. Chemosynthesis and photosynthesis are alike in that both  
(a) Are associated with heterotroph  
(b) Require sunlight as an energy source  
(c) Methods of autotrophic nutrition  
(d) Occur in tracheophytes
22. Ribulose diphosphate carboxylase oxygenase is located in  
(a) Mitochondria (b) Chloroplasts  
(c) Peroxisomes (d) Golgi bodies
23. The percentage of light energy utilized for photosynthesis by higher plants is [Odisha JEE 2008]  
(a) 100% (b) 50 %  
(c) 10% (d) 1 to 2%
24. During photosynthesis [BHU 1995; CPMT 1998, 2003; Pb. PMT 2000, 03; RPMT 2005]  
(a) Both CO<sub>2</sub> and water get oxidized  
(b) Both CO<sub>2</sub> and water get reduced  
(c) Water is reduced and CO<sub>2</sub> is oxidized  
(d) Carbon dioxide get reduced, water get oxidised and ATP is formed
25. Intensity of light can be measured by  
(a) Luxmeter (b) Wilmott's bubbler  
(c) Ganong's potometer (d) Farmer's potometer
26. Assimilatory power refers to [AFMC 1994]  
(a) Generation of ATP and NADPH<sub>2</sub>  
(b) Reduction of CO<sub>2</sub>  
(c) Splitting of water  
(d) Disintegration of plastids
27. Grana refers to  
(a) Stacks of thylakoids in plastids of higher plants  
(b) A constant in quantum equation  
(c) Glycolysis of glucose  
(d) Bye product of photosynthesis
28. Intact chloroplast from green leaves can be isolated by  
(a) Acetone (b) Ethanol  
(c) Alcohol (d) Sugar solution
29. Dimorphic chloroplasts are present in [MHCET 2002; WB JEE 2008, 10]  
(a) Sugarcane(C<sub>4</sub>) (b) Cotton  
(c) Pea (d) Mango
30. Phenomenon which converts light energy into chemical energy is [AFMC 2005]  
(a) Respiration (b) Photosynthesis  
(c) Transpiration (d) None of these
31. For the process of photosynthesis all except one of the following items are essential. Point out the exception  
(a) Water, minerals  
(b) Light, chlorophyll  
(c) CO<sub>2</sub>, optimum temperature  
(d) Oxygen, sucrose

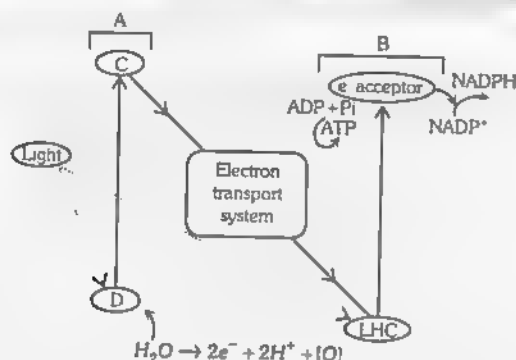
32. Plants are known as purifiers of air due to process of  
[MP PMT 1996; WB JEE 2008]  
(a) Respiration (b) Photosynthesis  
(c) Transpiration (d) Desiccation
33. In the overall process of photosynthesis, the number of  $\text{CO}_2$ , water, sugar and  $\text{O}_2$  molecules utilized and produced is  
[AMU (Med.) 2012]  
(a) 12 (b) 13  
(c) 19 (d) 31
34.  $\text{CO}_2$  is formed in all of the following except  
(a) Burning of sugar (b) Respiration in plants  
(c) Photosynthesis by plants (d) On heating of limestone
35. Quantasomes contain  
(a) 200 chlorophyll molecules (b) 230 chlorophyll molecules  
(c) 250 chlorophyll molecules (d) 300 chlorophyll molecules
36. Which one of the following is energy currency of the cell or The common immediate source of energy in cellular activity is  
[MH CET 2000]  
(a) Phosphate (b) ATP  
(c) ADP (d) AMP
37. For photosynthesis (i.e. for the synthesis of organic matter), the green plants need only  
(a) Light (b) Chlorophyll  
(c)  $\text{CO}_2$  and water (d) All of these
5. Consider the following statements  
(A) The portion of the spectrum between 500nm and 800nm is also referred to as photosynthetically active radiation (PAR)  
(B) Magnesium, calcium and chloride ions play prominent roles in the photolysis of water  
(C) In cyclic photophosphorylation, oxygen is not released (as there is no photolysis of water) and NADPH is also not produced  
Of these statements given above [Kerala PMT 2008]  
(a) A is true, but B and C are false  
(b) A and B are false, but C is true  
(c) B is true, but A and C are false  
(d) A and B are true, but C is false  
(e) A and C are true, but B is false
6. Consider the following statements regarding photosynthesis  
(A) ATP formation during photosynthesis is termed as photophosphorylation  
(B) Kranz anatomy pertains to leaf  
(C) Reduction of  $\text{NADP}^+$  to NADPH occurs during Calvin cycle  
(D) In a chlorophyll molecule magnesium is present in phytol tail  
Of the above statements [Kerala PMT 2008]  
(a) (A) and (B) are correct  
(b) (C) and (D) are correct  
(c) (A) and (C) are correct  
(d) (A) and (D) are correct  
(e) (B) and (C) are correct
7. Which pigment of the plant takes part in light reaction of photosynthesis  
[MHCET 2002; Odisha JEE 2009; CPMT 2010]  
Or  
Which pigment is present universally in all green plants  
[MP PMT 1999]  
(a) Xanthophyll (b) Chl-a  
(c) Carotene (d) Phycoxanthin

### Light reaction/Pigments

1. Manganese and Chlorine is required in [NCERT; BHU 2005; CBSE PMT 2009; Kerala PMT 2009, 10; CBSE PMT (Maine) 2011; CBSE PMT (Pre.) 2012; AIPMT 2015]  
(a) Nucleic acid synthesis  
(b) Plant cell wall formation  
(c) Photolysis of water during photosynthesis  
(d) Chlorophyll synthesis
2. Stroma in the chloroplasts of higher plant contains  
[CBSE PMT 2009; AIPMT 2015]  
(a) Light-independent reaction enzymes  
(b) Light-dependent reaction enzymes  
(c) Ribosomes  
(d) Chlorophyll
3. Number of thylakoids in a granum is [AFMC 2008]  
(a) 5-10 (b) 2-100  
(c) 100-150 (d) 150-200
4. Consider the following statements with respect to photosynthesis  
A. The first carbon dioxide acceptor in  $\text{C}_4$  cycle is PGA  
B. In  $\text{C}_3$  plants, the first stable product of photosynthesis during dark reaction is RuBP  
C. Cyclic photophosphorylation results in the formation of ATP  
D. Oxygen which is liberated during photosynthesis comes from water  
Of the above statements [Kerala PMT 2012]  
(a) A and B alone are correct (b) A and C alone are correct  
(c) C and D alone are correct (d) B and C alone are correct  
(e) B and D alone are correct
8. Photosynthetic pigments in chloroplast are embedded in membrane of [CBSE PMT 1991]  
(a) Thylakoids (b) Photoglobulin  
(c) Matrix (d) Envelope of chloroplast
9. The visible portion of light spectrum useful in photosynthesis is referred to as [MHCET 2015]  
(a) RFLP (b) PAR  
(c) VAM (d) VNTR
10. Which of the following pigment is yellow in colour  
(a) Chlorophyll 'a' (b) Chlorophyll 'b'  
(c) Carotene (d) Xanthophyll

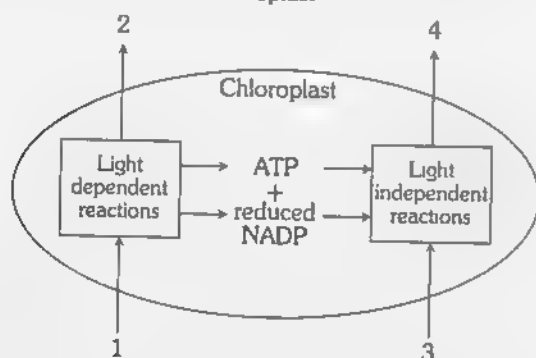


11.



Which of the following is correctly labelled for the given figure [AIIMS 2012]

- (a) A : PS II; B : PS I; C :  $e^-$  acceptor; D : LHC  
 (b) A : LHC; B :  $e^-$  acceptor; C : PS I; D : PS II  
 (c) A : PS I; B : PS II; C :  $e^-$  acceptor; D : LHC  
 (d) A :  $e^-$  acceptor; B : LHC; C : PS II; D : PS I
12. Which of the following wavelength occur in red part of the spectrum  
 (a) 470 nm (b) 390 nm  
 (c) 680 nm (d) 830 nm
13. Which of the following statement is true with regard to the light reaction of photosynthetic mechanism in plants [Kerala PMT 2006]  
 (a) Chlorophyll A occurs with peak absorption at 680 nm in photosystem I and at 700 nm in photosystem II.  
 (b) Magnesium and sodium ions are associated with photolysis of water molecules.  
 (c)  $O_2$  is evolved during cyclic photophosphorylation.  
 (d) Photosystems I and II are both involved in non-cyclic photophosphorylation  
 (e) Both ATP and  $NADPH_2$  are formed during cyclic photophosphorylation
14. Excitation of chlorophyll due to light is a [BHU 2012]  
 (a) Photooxidation reaction (b) Endergonic reaction  
 (c) Thermochemical reaction (d) Photochemical reaction
15. The given diagram indicates the movement of substances into in and out of a chloroplast



What do labels 1 to 4 represent

[NCERT]

	1	2	3	4
(a)	Sugar	$H_2O$	ATP	$O_2$
(b)	$H_2O$	$O_2$	$CO_2$	Sugar
(c)	$CO_2$	$H_2O$	Sugars	$O_2$
(d)	$CO_2$	ATP	$H_2O$	Starch

16. Solarization is

[BHU 2005]

- (a) Formation of chlorophyll  
 (b) Destruction of chlorophyll  
 (c) Utilisation of sunlight  
 (d) Effects of solar light
17. Which statement about photosynthesis is false [KCET 2009]  
 (a) The electron carriers involved in photophosphorylation are located on the thylakoid membranes  
 (b) Photosynthesis is a redox process in which water is oxidised and carbon dioxide is reduced  
 (c) The enzymes required for carbon fixation are located only in the grana of chloroplasts  
 (d) In green plants, both PS-I and PS-II are required for the formation of  $NADPH + H^+$
18. Which one of the following is not true about the light reactions of photosynthesis [Kerala PMT 2009]  
 (a) Light energy provides energy for the photolysis of water through excitation of the reaction centre of PS II  
 (b) The flow of electrons from water to NADP in non-cyclic electron transport produces one ATP  
 (c) Reactions of the two photosystems are needed for the reduction of NADP  
 (d)  $P_{680}$  and  $P_{700}$  are the reaction centres of PS I and PS II respectively  
 (e) NADPH is not produced in cyclic electron transport in light reactions
19. Which of the following is photophosphorylation [WB JEE 2008]  
 (a) Production of ATP from ADP  
 (b) Production of NADP  
 (c) Synthesis of ADP from ATP  
 (d) Production of PGA
20. In chlorophyll structure four pyrrole rings are united with Mg by their atoms of [AMU (Med.) 2009]  
 (a) N (b) C  
 (c) H (d) O
21. The first acceptor of electrons from an excited chlorophyll molecule of photosystem II is [CBSE PMT 2007, 08]  
 (a) Cytochrome  
 (b) Iron-sulphur protein  
 (c) Ferredoxin  
 (d) Quinone
22. DCMU [MP PMT 2007]  
 (a) Inhibits PS-I  
 (b) Inhibits PS-II  
 (c) Destroy chloroplast  
 (d) Inhibits oxidative phosphorylation

23.  $\text{NADPH}_2$  is generated through [CBSE PMT 1997]

Or

Ferredoxin is a component of [CBSE PMT 1991]

- (a) Glycolysis (b) Photosystem-I  
(c) Photosystem-II (d) Anaerobic respiration

24. Photolysis of each water molecule in light reaction will yield [Kerala PMT 2007]

- (a) 2 electrons and 4 protons  
(b) 4 electrons and 4 protons  
(c) 4 electrons and 3 protons  
(d) 2 electrons and 2 protons  
(e) 1 electron and 2 protons

25. Which of the following statements is true with regard to the light reaction of photosynthesis [Kerala PMT 2011]

- (a) In PS II the reaction centre chlorophyll *a* has an absorption peak at 700 nm, hence is called P 700  
(b) In PS I the reaction centre chlorophyll *a* has an absorption maxima at 680 nm and is called P 680  
(c) The splitting of water molecule is associated with PS I  
(d) Photosystems I and II are involved in Z scheme  
(e) Lamellae of the grana have PS I and PS II and stroma lamellae membranes have PS II only

26. Which one of the following statements about the events of noncyclic photophosphorylation is not correct [KCET 2010; J & K CET 2012]

- (a) Only one photosystem participates  
(b) ATP and NADPH are produced  
(c) Photolysis of water takes place  
(d)  $\text{O}_2$  is released

27. In which stage of photosynthesis, light is directly necessary [CPMT 1996]

- (a) For electron excitation  
(b) For reduction of  $\text{CO}_2$   
(c) For regulating photosystem  
(d) For cyclic photophosphorylation

28. The source of  $\text{O}_2$  liberated in photosynthesis in green plants is [CPMT 1994, 95; Bihar MDAT 1992; MP PMT 1999, 2002, 10, 12; RPMT 1999]

- (a) Photosynthetic enzyme  
(b) Carbohydrate present in leaf  
(c) Water  
(d) Carbon dioxide

29. Photolysis of water takes place in [CPMT 1995]

- (a) Calvin cycle (b) Glycolysis  
(c) Light phase (d) Dark phase

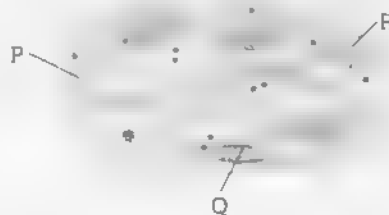
30. The site of oxygen evolution and photosynthetic phosphorylation in chloroplast are

- (a) Matrix (b) Grana stacks  
(c) Inner wall of chloroplast (d) Surface of chloroplast

31. The specific function of light energy in the process of photosynthesis is to

- (a) Activate chlorophyll (b) Split water  
(c) Reduce carbon dioxide (d) Synthesize glucose

32. The given diagram shows the ultra structure of a chloroplast as seen in section. Identify the functions of P, Q and R [NCERT]



	P	Q	R
(a)	Light reaction	Carbohydrate synthesis	Carbohydrate storage
(b)	Light reaction	Carbohydrate storage	Carbohydrate synthesis
(c)	Light reaction	Carbohydrate synthesis	Carbohydrate storage
(d)	Carbohydrate storage	Carbohydrate synthesis	Light reaction

33. NADP is converted into  $\text{NADPH}_2$  in

- (a) Photosystem-I  
(b) Non-cyclic photophosphorylation  
(c) Calvin cycle  
(d) Photosystem-II

34. The creation of proton gradient across the thylakoid membrane is a result of [AMU (Med.) 2010]

- (a) Decrease in proton number in stroma  
(b) Accumulation of protons in the lumen  
(c) Decrease in the pH in the lumen  
(d) All of the above

35. Read the following four statements. A, B, C and D and select the right option having both correct statements.

**Statements**

- (A) Z scheme of light reaction takes place in presence of PS I only  
(B) Only PS I is functional in cyclic photophosphorylation  
(C) Cyclic photophosphorylation results into synthesis of ATP and  $\text{NADPH}_2$   
(D) Stroma lamellae lack PS II as well as NADP

**Options** [CBSE PMT (Maine) 2010]

- (a) (B) and (D) (b) (A) and (B)  
(c) (B) and (C) (d) (C) and (D)

36. Photosynthetic unit is [MP PMT 2003]

- (a) Glyoxysome (b) Spherosome  
(c) Microsome (d) Quantasome

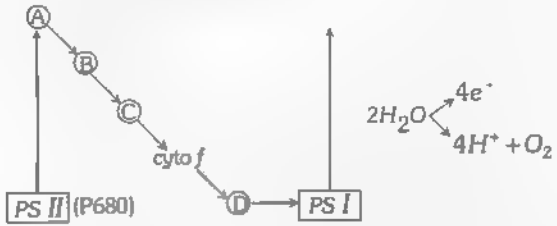
37.  $\text{P}_{700}$  is a special form of which pigment [RPMT 1997]

- (a) Chlorophyll b (b) Carotenes  
(c) Chlorophyll a (d) Phycobilins

38. Water soluble pigments found in plant cell vacuoles are [CPMT 1994; BVP 2000; WB JEE 2011; BHU 2012; NEET (Phase-I) 2016]

- (a) Chlorophyll (b) Carotene  
(c) Anthocyanin/phyco bilin (d) Xanthophyll

39. Where does the primary photochemical reaction occur in chloroplast or Where does the light reactions of photosynthesis take place or Light reaction takes place in  
[CPMT 1995, 98; RPMT 1995, 99; MP PMT 1999; Pb. PMT 1999, 2000]
- Stroma
  - Endoplasmic reticulum
  - Quantasome or thylakoids (Grana)
  - Inner membrane of chloroplast
40. The trapping centre of light energy in photosystem-I is  
[BHU 2000; BVP 2003]
- Or
- Pigment system-I receives radiant energy and releases electron  
[MP PMT 1992]
- P-660
  - P-680
  - P-700
  - P-720
41. Blue-green algae shows
- Chlorophyll 'a'
  - Chlorophyll 'b'
  - Both (a) and (b)
  - None of the above
42. Pigment system-I conducts  
[Odisha JEE 2011]
- Cyclic photophosphorylation
  - Non-cyclic photophosphorylation
  - Both (a) and (b)
  - None of the above
43. Pigment system-II is concerned with  
[MHCET 2000; BHU 2003]
- Photolysis of water
  - Reduction of  $\text{CO}_2$
  - Flowering
  - None of the above
44. The role of chlorophyll in photosynthesis is  
[CBSE PMT 2002]
- Absorption of  $\text{CO}_2$
  - Absorption of light
  - Absorption of light and photochemical decomposition of water
  - Absorption of water
45. Photophosphorylation is a process in which [MP PMT 1996]
- Light energy is converted into chemical energy in the form of ATP
  - NADP is formed
  - Chemical energy is used to produce ATP
  - $\text{CO}_2$  is reduced to carbohydrate
46. Which one of the following statements about cytochrome  $\text{P}_{450}$  is wrong  
[CBSE PMT 1998]
- It has an important role in metabolism
  - It contains iron
  - It is a coloured cell
  - It is an enzyme involved in oxidation reactions
47. Chlorophyll is present
- On the surface of chloroplast
  - In the stroma of chloroplast
  - In the grana of chloroplast
  - Dispersed throughout the chloroplast
48. Through which of the following substances the photosystem-I passes an electron to NADP during light reactions
- Plastocyanin
  - Plastoquinone
  - Cytochrome
  - Ferredoxin
49. During photochemical reactions of photosynthesis [NCERT; RPMT 1999; KCET 1994; MDAT 1995]
- Liberation of oxygen takes place
  - Formation of ATP and  $\text{NADPH}_2$  take place
  - Liberation of  $\text{O}_2$  and formation of ATP and  $\text{NADPH}_2$  take place
  - Assimilation of  $\text{CO}_2$  takes place
50. The core metal of chlorophyll is  
[CBSE PMT 1997, 99; AFMC 1999; CPMT 2005]
- Or
- Which element is left when chlorophyll is burnt [CPMT 1993]
- Fe
  - Mg
  - Ni
  - Cu
51. Hill's reaction takes place in
- Dark
  - Light
  - Dark and light both
  - At any time
52. In photosynthesis light energy is utilized in  
[Bihar MDAT 1995; CPMT 1998; MHCET 2003; Odisha JEE 2005]
- Converting ATP into ADP
  - Changing  $\text{CO}_2$  into carbohydrate
  - Converting ADP into ATP
  - All of the above
53. Main pigment involved in transfer of electrons in photosynthesis is  
[CPMT 1998]
- Cytochrome
  - Phytochrome
  - Both (a) and (b)
  - None of these
54. ATP is produced during [MH CET 2004; MP PMT 2005; CBSE PMT 2009]
- Cyclic photosynthesis
  - Non cyclic photosynthesis
  - Both
  - None
55. Splitting of water in photosynthesis is called  
[Pb. PMT 2000, 04; MHCET 2001]
- Dark reaction
  - Electron transfer
  - Photolysis
  - Phototropism
56. Chlorophyll is [MP PMT 1996; BVP 2002]
- Soluble in organic solvents
  - Soluble in water
  - Soluble in both organic solvents and water
  - None of the above
57. In noncyclic photophosphorylation, the pigment molecule first excited is  
[MHCET 2004]
- $\text{P}_{680}$
  - $\text{P}_{700}$
  - Chlorophyll-b
  - Xanthophyll
58. The 'Z' scheme of photosynthesis was proposed by
- Hill and Bendall
  - Emerson
  - Arnon
  - Rabinowitch and Govindjee

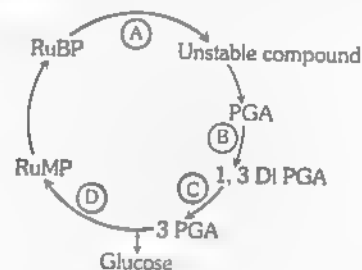
59. Hill's law in photosynthesis shows [CPMT 1996]  
 (a) Electron excitation (b) Removal of water  
 (c) Fixation of  $\text{CO}_2$  (d)  $\text{O}_2$  is obtained from water
60. Chloroplasts absorb light of wavelength [CPMT 1994]  
 (a) 200 – 300  $m\mu$  (b) 800 – 1000  $m\mu$   
 (c) 460 – 660  $m\mu$  (d) 300 – 400  $m\mu$
61. The reaction centre for PS-I and PS- II are [NCERT; MP PMT 2003]  
 (a)  $P_{700}$  and  $P_{680}$  respectively (b)  $P_{680}$  and  $P_{700}$  respectively  
 (c)  $P_{580}$  and  $P_{700}$  respectively (d)  $P_{700}$  and  $P_{580}$  respectively
62. Photo-oxidation of water results in the formation of [Odisha JEE 2012]  
 (a)  $\text{H}^+$ ,  $\text{O}_2$  and ATP (b)  $\text{H}^+$ ,  $\text{O}_2$ ,  $e^-$  and ATP  
 (c)  $\text{H}^+$ ,  $\text{O}_2$  and  $e^-$  (d) None of these
63. Photosystem-I contains [RPMT 1992]  
 (a)  $\text{Chl} - a$ ,  $\text{Chl} - b$ , carotenoid and  $P_{680}$   
 (b)  $\text{Chl} - a$ ,  $\text{Chl} - b$  and  $P_{680}$   
 (c)  $\text{Chl} - a$ ,  $\text{Chl} - b$  and  $P_{700}$   
 (d)  $\text{Chl} - a$ , xanthophyll and  $P_{700}$
64. Which one of the following elements is required for photosynthetic oxygen evolution [MP PMT 1998; AMU (Med.) 2012]  
 (a) Copper (b) Iron  
 (c) Manganese (d) Zinc
65. Photolysis of water by isolated chloroplasts was demonstrated by [AIIEE Pharmacy 2004]  
 (a) Robin Hill (b) Van Niel  
 (c) Liebig (d) Calvin
66. Photosynthetically active radiation (PAR) represents the following range of wavelength [CBSE PMT 1996, 2005; AIIMS 2007; BHU 2012]  
 (a) 340–450  $nm$  (b) 400–700  $nm$   
 (c) 500–600  $nm$  (d) 450–950  $nm$
67. Plants adapted to low light intensity have [CBSE PMT 2004]  
 (a) More extended root system  
 (b) Leaves modified to spines  
 (c) Larger photosynthetic unit size than the sun plants  
 (d) Higher rate of  $\text{CO}_2$  fixation than the sun plants
68. Hill reaction occurs in [AIIMS 2003]  
 (a) High altitude plants (b) Total darkness  
 (c) Absence of water (d) Presence of ferredoxin
69. ATP formation in photosynthesis is known as [MP PMT 1993, 2006; CPMT 1998]  
 (a) Phosphorylation  
 (b) Photophosphorylation  
 (c) Oxidative phosphorylation  
 (d) None of the above
70. In photosystem-I, the first electron acceptor is [CBSE PMT 2006]  
 (a) Plastocyanin (b) An iron-sulphur protein  
 (c) Ferredoxin (d) Cytochrome
71. During non-cyclic photophosphorylation in which of the following,  $4e^-$  produced through photolysis will enter [GUJCET 2007]  
 (a) PS – II (b) PC  
 (c) PQ (d) PS – I
72.  $\text{O}_2$  evolution is directly associated with [DPMT 2003; BVP 2004]  
 Or  
 Which of the following does not participate when the light reaction synthesizes only ATP or performs the cyclic flow of electrons  
 (a) PS – I (b) PS – II  
 (c) Phytochrome (d) Phycocyanin
73.  $\text{H}_2$  donor during photosynthesis is [CPMT 2010]  
 (a) NADH (b) NADP  
 (c) ATP (d) NADPH
74. The wavelength of light most absorbed during photosynthesis is [MP PMT 1998]  
 (a) 440  $nm$  (b) 550  $nm$   
 (c) 660  $nm$  (d) 700  $nm$
75. The light absorbed by the chlorophyll is at the wave length of [MP PMT 2002]  
 (a) 400  $nm$  (b) 500  $nm$   
 (c) 600  $nm$  (d) 660  $nm$
76. Number of chlorophyll arranged per reaction centre in the light harvesting complex are [Odisha JEE 2005]  
 (a) 100 (b) 200  
 (c) 400 (d) 500
77. Photosystem I and Photosystem II are found in [CBSE PMT 1992; RPMT 1999; BHU 2001; MP PMT 2001]  
 (a) Stroma of chloroplast  
 (b) Grana of chloroplast  
 (c) Matrix of mitochondria  
 (d) Inner membrane of mitochondria
78. Which fractions of the visible spectrum of solar radiations are primarily absorbed by carotenoids of the higher plants [CBSE PMT 1999]  
 (a) Violet and blue (b) Blue and green  
 (c) Green and red (d) Red and violet
79. Chlorophyll 'a' and 'b' shows maximum absorption in [NCERT]  
 (a) Blue region  
 (b) Red region  
 (c) Blue and red regions  
 (d) Yellow and violet regions
80.   
 In the above schematic diagram, which is plastocyanin [KCET 2007]  
 (a) C (b) D  
 (c) A (d) B

81. How chlorophyll would appear when seen in red light  
(a) Red (b) Green  
(c) Black (d) Colourless
82. Which one of the following concerns photophosphorylation  
[CBSE PMT 1999]  
(a)  $\text{AMP} + \text{Inorganic } \text{PO}_4 \xrightarrow{\text{Light energy}} \text{ATP}$   
(b)  $\text{ADP} + \text{AMP} \xrightarrow{\text{Light energy}} \text{ATP}$   
(c)  $\text{ADP} + \text{Inorganic } \text{PO}_4 \xrightarrow{\text{Light energy}} \text{ATP}$   
(d)  $\text{ADP} + \text{Inorganic } \text{PO}_4 \rightarrow \text{ATP}$
83. Who revealed the chemical composition of chlorophyll carotene and xanthophyll  
(a) Govindjee (b) Willstatter and Stoll  
(c) Park and Biggins (d) Meyers and French
84. Which one is  $\text{Cu}^{++}$  containing pigment  
[CPMT 1999, 2003; MP PMT 2003]  
(a) Ferredoxin (b) Plastocyanin  
(c) Plastoquinone (d) Cytochrome
85. The chlorophylls absorb visible light in the region of following wavelengths  
[BHU 1994]  
(a) 400 nm to 500 nm only  
(b) 600 nm to 800 nm only  
(c) 400 nm to 500 nm and 600 nm to 700 nm  
(d) 300 nm to 400 nm only

### Dark reaction

1. Dark reaction of photosynthesis is called  
(a) Aphotic action (b) Black action  
(c) Blackman's reaction (d) None of the above
2. The Calvin cycle proceeds in three stages  
1. Reduction, during which carbohydrate is formed at the expense of the photochemically made ATP and NADPH  
2. Regeneration, during which the carbon dioxide acceptor ribulose-1, 5-biphosphate is formed  
3. Carboxylation, during which carbon dioxide combines with ribulose-1, 5-biphosphate  
Identify the correct sequence [Kerala PMT 2006]  
(a) 3-1-2 (b) 3-2  
(c) 1-2-3 (d) 2-1-3  
(e) 1-3-2
3. PGA as the first  $\text{CO}_2$  fixation product was discovered in photosynthesis of [CBSE PMT (Pre.) 2010]  
(a) Alga (b) Bryophyte  
(c) Gymnosperm (d) Angiosperm
4. Identify the incorrect statement with respect to Calvin cycle [KCET 2009]  
(a) The carboxylation of RuBP is catalysed by rubisco  
(b) The first stable intermediate compound formed is phosphoglycerate  
(c) 18 molecules of ATP are synthesized during carbon fixation  
(d)  $\text{NADPH} + \text{H}^+$  produced in light reaction is used to reduce diphosphoglycerate

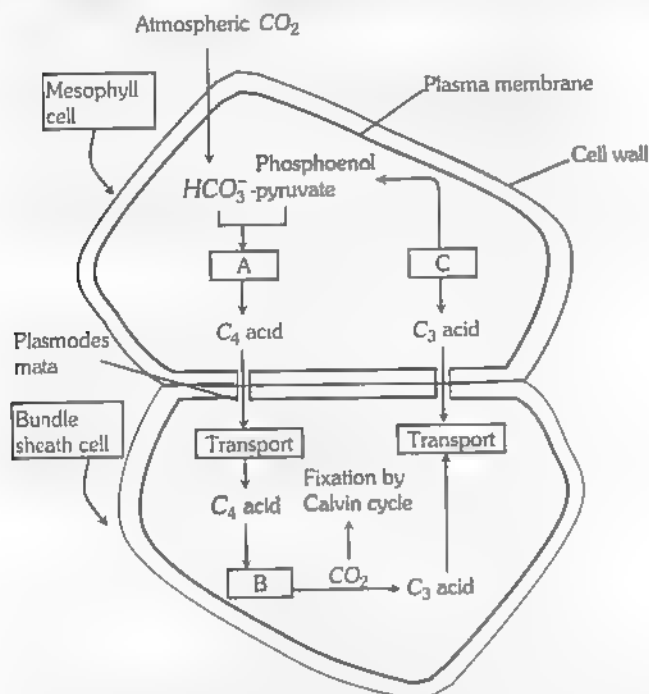
5. The enzyme responsible for primary carboxylation in  $\text{C}_3$  plants is [Kerala PMT 2009]  
(a) Hexokinase  
(b) Succinic dehydrogenase  
(c) Pyruvate carboxylase  
(d) RuBP carboxylase oxygenase  
(e) PEP carboxylase
6. In a condensed schematic representation of dark reaction of photosynthesis given below, steps are indicated by alphabets. Select the option where the alphabets are correctly identified



[KCET 2012]

- (a) A =  $\text{CO}_2$  fixation, B = Reduction, C = Phosphorylation, D = Regeneration  
(b) A = Regeneration, B =  $\text{CO}_2$  fixation, C = Reduction, D = Phosphorylation  
(c) A =  $\text{CO}_2$  fixation, B = Phosphorylation, C = Reduction, D = Regeneration  
(d) A =  $\text{CO}_2$  fixation, B = Phosphorylation, C = Regeneration, D = Reduction
7. If bundle sheath cells of the  $\text{C}_4$  plants are infected by an organism, which utilize  $\text{CO}_2$  efficiently then which process will be affected very first [GUJCET 2014]  
(a)  $\text{PGAL} \rightarrow \text{RUBP}$   
(b)  $\text{PGAL} + \text{PGA} \rightarrow \text{Glucose}$   
(c)  $\text{PGA} \rightarrow \text{PGAL}$   
(d)  $\text{RUBP} \rightarrow \text{PGA}$
8. For the same amount of  $\text{CO}_2$  fixed, a  $\text{C}_4$  plant, in comparison with a  $\text{C}_3$  plant, loses only [AMU (Med.) 2009,10]  
(a) Half amount of water (b) Equal amount of water  
(c) Double amount of water (d) None of these
9. Which of the following is the main product in the photorespiration of  $\text{C}_3$  plants [CPMT 1999; MP PMT 2010, 12]  
(a) Phosphoglycerate (b) Phosphoglycolate  
(c) Glycerate (d) Glycolate
10. During Calvin cycle the total number of  $\text{CO}_2$ , ATP and NADPH molecules utilized and glucose, ADP and NADP molecules generated is [AMU (Med.) 2012]  
(a) 31 (b) 36  
(c) 61 (d) 67
11.  $\text{CO}_2$  joins the photosynthetic pathway during [MP PMT 1999]  
(a) Light reaction (b) Dark reaction  
(c) Photosystem-I (d) Photosystem-II

12. Study the pathway given below



In which of the following options correct words for all the three blanks A, B and C are indicated

[NCERT; CBSE PMT (Malina) 2010]

	A	B	C
(a)	Decarboxylation	Reduction	Regeneration
(b)	Fixation	Transamination	Regeneration
(c)	Fixation	Decarboxylation	Regeneration
(d)	Carboxylation	Decarboxylation	Reduction

13. The initial enzyme of Calvin cycle is [VITEEE 2008]  
 (a) Ribulose 1, 5-diphosphate carboxylase  
 (b) Triose phosphate dehydrogenase  
 (c) Phosphopentokinase  
 (d) Cytochrome oxidase
14. During photosynthesis when PGA is changed into phosphoglyceraldehyde, which of the following reaction occur  
 (a) Oxidation (b) Reduction  
 (c) Electrolysis (d) Hydrolysis
15. Ribulose diphosphate carboxylase enzyme catalyses the carboxylation reaction between [MP PMT 2013]  
 (a) Oxaloacetic acid and acetyl CoA  
 (b)  $\text{CO}_2$  and ribulose 1, 5 diphosphate  
 (c) Ribulose diphosphate and phosphoglyceraldehyde  
 (d) PGA and dihydroxy acetone phosphate
16. Calvin cycle occur in [MP PMT 1996; BVP 2002]  
 (a) Chloroplasts (b) Cytoplasm  
 (c) Mitochondria (d) Glyoxysomes
17. During dark reaction of photosynthesis  
 (a) Water split  
 (b)  $\text{CO}_2$  is reduced to organic compounds  
 (c) Chlorophyll is activated  
 (d) 6 carbon sugar is broken down into 3 carbon sugar

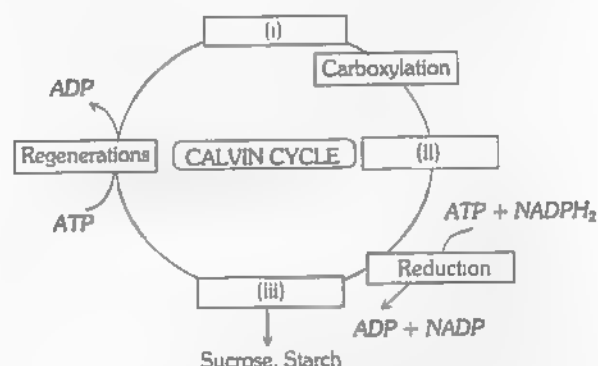
18. 3-PGA is first stable product in [DPMT 2007]  
 (a) Carbon-reduction cycle (b) OAA  
 (c) Malic acid (d) PEP

19. In  $\text{C}_3$  plants, the first stable product of photosynthesis during dark reaction is

[CPMT 1992, 2009; BHU 1995; RPMT 1995; CBSE PMT 1995; KCET 1998; MP PMT 2000, 06; BVP 2000, 09; DPMT 2006; Kerala PMT 2009]

- (a) 3-phosphoglyceric acid (b) Phosphoglyceraldehyde  
 (c) Malic acid (d) Oxaloacetic acid

20. Choose the correct combinations of labelling the carbohydrate molecule involved in the Calvin cycle.



[NCERT; Kerala PMT 2007]

- (a) (i) RuBP (ii) Triose phosphate (iii) PGA  
 (b) (i) PGA (ii) RuBP (iii) Triose phosphate  
 (c) (i) PGA (ii) Triose phosphate (iii) RuBP  
 (d) (i) RuBP (ii) PGA (iii) Triose phosphate  
 (e) (i) Triose phosphate (ii) PGA (iii) RuBP
21. One molecule of glucose in Calvin cycle is formed from [KCET 2006; Odisha JEE 2010]  
 (a)  $6\text{CO}_2 + 12\text{ATP}$   
 (b)  $6\text{CO}_2 + 30\text{ATP} + 12\text{NADPH}$   
 (c)  $6\text{CO}_2 + 18\text{ATP} + 12\text{NADPH}$   
 (d)  $6\text{CO}_2 + 18\text{ATP} + 30\text{NADPH}$
22. Calvin cycle is [CPMT 1995]  
 (a) Dependent on light (b) Not dependent on light  
 (c) Occurs in light (d) None of these
23. How many Calvin cycle form one hexose molecule [CBSE PMT 1996, 2000]  
 (a) 2 (b) 6  
 (c) 4 (d) 8
24.  $\text{CO}_2$  acceptor in  $\text{C}_3$  plants is [CBSE PMT 1995, 96,99; CPMT 1999, 2001; RPMT 2002, 06; J & K CET 2008; WB JEE 2009; AFMC 2010]  
 (a) Xylulose-5-phosphate  
 (b) 3-phosphoglyceric acid  
 (c) Ribulose 1, 5-diphosphate  
 (d) Phosphoenol pyruvic acid
25. Which of the following is present in Calvin cycle [CBSE PMT 1996; AFMC 2008]  
 (a) Photophosphorylation  
 (b) Oxidative carboxylation  
 (c) Reductive carboxylation  
 (d) Oxidative phosphorylation

26. In  $C_3$  plants, photosynthesis occur in [J & K CET 2010]  
 (a) Bundles sheath cells (b) Peroxisome  
 (c) Mesophyll cells (d) Kranz anatomy
27. In which plant Calvin experimented by radioactive isotopy to discover the stable product of  $C_3$  cycle [Odisha JEE 2005]  
 (a) *Chlorella* (b) *Cycas*  
 (c) Carrot (d) Tobacco
28. Radioactive  $C^{14}$  is given to  $CO_2$  and released to atmosphere. This  $CO_2$  is taken by RuBP in a  $C_3$  plant. First radioactive  $C^{14}$  is seen in which compound [Manipal 2005]  
 (a) PGAL (b) PEP  
 (c) RMP (d) PGA
29. The first step in dark reaction of photosynthesis is [CPMT 2004]  
 (a) Formation of ATP  
 (b) Ionization of water  
 (c) Attachment of  $CO_2$  to a pentose sugar  
 (d) Excitement of electron of chlorophyll by a photon of light
30. Which of the following is the first compound that accepts carbon dioxide during dark phase of photosynthesis [BHU 2004]  
 (a) NADP (b) RuBP  
 (c) Ferredoxin (d) Cytochrome
31. Number of carboxylation occur in Calvin cycle, is [DPMT 2004]  
 (a) 0 (b) 1  
 (c) 2 (d) 3
32. Reducing power which is transferred from light reaction of photosynthesis to the dark reaction is [AFMC 2012]  
 (a) ATP (b) NADPH  
 (c) NADH (d)  $FADH_2$
4. In  $C_4$  plants, the bundle sheath cells [DUMET 2009; NEET (Karnataka) 2013]  
 (a) Have thin walls of facilitate the gaseous exchange  
 (b) Have large intercellular spaces  
 (c) Are rich in PEP carboxylase  
 (d) Have a high density of chloroplasts and rich in RuBisCo
5. The ratio between 2-carbon and 3-carbon intermediates having  $-NH_2$  group formed in photosynthetic oxidation cycle is [EAMCET 2009]  
 (a) 1 : 1 (b) 2 : 1  
 (c) 3 : 2 (d) 3 : 4
6. The first carbon fixation in  $C_4$  pathway occurs in chloroplasts of [CBSE PMT 1995; MP PMT 1997; WB JEE 2008]  
 (a) Guard cells (b) Mesophyll cells  
 (c) Bundle sheath cells (d) Epidermal cells
7. An alternate  $CO_2$  fixation mechanism was found some tropical species of grass family by Hatch and Slack, who were from [AMU (Med.) 2009]  
 (a) England (b) USA  
 (c) Australia (d) New Zealand
8. In a CAM plant the concentration of organic acid [WB JEE 2009]  
 (a) Increases during the day  
 (b) Decreases or increases during the day  
 (c) Increases during night  
 (d) Decreases during any time
9. In photorespiration, what is the role of peroxisome [GUJCET 2007]  
 (a) Help in oxidation of glycolate  
 (b) Help in oxygenation of glycolate  
 (c) Help in synthesis of PGA  
 (d) Help in reduction of glyoxylate
10. During photorespiration, the oxygen consuming reaction (s) occur in [CBSE PMT 2006]  
 (a) Grana of chloroplasts and peroxisomes  
 (b) Stroma of chloroplasts  
 (c) Stroma of chloroplasts and mitochondria  
 (d) Stroma of chloroplasts and peroxisomes
11. The energy wastage occurs during  
 (a) Dark respiration (b) Photosynthesis  
 (c) Glycolysis (d) Photorespiration
12. ....are CAM plant [Odisha JEE 2005; KCET 2011]  
 (a) Maize, papaya (b) Pineapple, agave  
 (c) Onion, mango (d) Pea, sugarcane
13. Which one is a  $C_4$  plant [MP PMT 1993, 95; VITEEE 2006]  
 (a) Sorghum (b) Tribulus  
 (c) Maize (d) All of these
14. Photorespiration shows formation of [AIIMS 2012]  
 (a) Sugar but not ATP (b) ATP but not sugar  
 (c) Both ATP and sugar (d) Neither ATP nor sugar

### $C_4$ /CAM/Photorespiration

1. The family in which many plants are  $C_4$  type  
 (a) Malvaceae (b) Solanaceae  
 (c) Crucifereae (d) Gramineae
2. Which of the following statements with regard to photosynthesis is/are correct  
 A. In  $C_4$  plants, the primary  $CO_2$  acceptor is PEP  
 B. In the photosynthetic process PS II absorbs energy at or just below 680 nm  
 C. The pigment that is present in the pigment system I is  $P_{683}$  [Kerala PMT 2008]  
 (a) B and C only (b) A only  
 (c) C only (d) A and B only  
 (e) A and C only
3. The  $C_4$  plants are photosynthetically more efficient than  $C_3$  plants because [CBSE PMT 2008; CBSE PMT (Pre.) 2010; AIIMS 2011]  
 (a) The  $CO_2$  efflux is not prevented  
 (b) They have more chloroplasts  
 (c) The  $CO_2$  compensation point is more  
 (d)  $CO_2$  generated during photorespiration is trapped and recycled through PEP carboxylase

15. In  $C_4$  plants, Calvin cycle occurs in  
[CBSE PMT 1994; CPMT 2005]  
(a) Stroma of bundle sheath chloroplast  
(b) Mesophyll chloroplast  
(c) Grana of bundle sheath chloroplast  
(d) Does not occur as  $CO_2$  is fixed mainly by PEP and no  $CO_2$  is left for Calvin cycle
16. Photorespiration is characteristic of  
[MP PMT 1994; BHU 1995, 2002]  
(a) CAM Plants (b)  $C_3$  Plants  
(c)  $C_4$  Plants (d) None of the above
17.  $C_4$  photosynthesis does not occur in  
[CPMT 1994; MP PMT 2000]  
(a) *Zea mays*  
(b) *Saccharum munja*  
(c) *Saccharum officinarum*  
(d) *Euphorbia splendens*
18. Which of the following is  $CO_2$  acceptor in  $C_4$  plants  
[NCERT; CBSE PMT 1990; CPMT 1994, 98, 2004, 09;  
BHU 1994, 2000, 01; EAMCET 1995; MP PMT 1996;  
Odisha PMT 2002; BVP 2002; MHCET 2002; RPMT 2006;  
Kerala PMT 2007; J & K CET 2010; NEET 2017]  
(a) Phosphoenol pyruvate (PEP)  
(b) Ribulose 1, 5-diphosphate (RuDP)  
(c) Oxaloacetic acid (OAA)  
(d) Phosphoglyceric acid (PGA)
19. Which of the following cycle shows oxaloacetic acid as first stable product  
[BHU 2008; J & K CET 2012]  
(a) Calvin cycle (b) Hatch and Slack cycle ( $C_4$ )  
(c)  $C_2$  cycle (d) None of the above
20. Kranz type of anatomy is found in  
[CBSE PMT 1990;  
RPMT 1995, 97; MH CET 2006; J & K CET 2008;  
AFMC 2009; CBSE PMT (Malna) 2010;  
AIIMS 2012; WB JEE 2016]  
(a)  $C_2$  plants (b)  $C_3$  plants  
(c)  $C_4$  plants (Sugarcane) (d) CAM plants
21. During photorespiration which compounds are formed having 2C and 3C respectively in Peroxisome  
[GUJCET 2015]  
(a) Glycolate, Glycine  
(b) Glycine, Glycerate  
(c) Serine, Glycine  
(d) Phosphoglycerate, Glycolate
22.  $C_4$  plants are adapted to  
[NCERT; BHU 2002]  
(a) Hot and dry climate (b) Temperate climate  
(c) Cold and dry climate (d) Hot and humid climate
23. Which one of the following is wrong in relation to photorespiration  
[CBSE PMT 2003]  
(a) It is a characteristic of  $C_3$  plants  
(b) It occurs in chloroplasts  
(c) It occurs in day time only  
(d) It is a characteristic of  $C_4$  plants

24. A plant in your garden avoids photorespiratory losses, has improved water use efficiency shows high rates of photosynthesis at high temperatures and has improved efficiency of nitrogen utilisation. In which of the following physiological groups would you assign this plant  
[NEET (Phase-I) 2016]  
(a)  $C_3$  (b)  $C_4$   
(c) CAM (d) Nitrogen fixer

25. Which one of the following is a CAM plant [MHCET 2015]  
(a) Maize (b) *Kalanchoe*  
(c) Sugarcane (d) Jowar

26. Select the incorrect matched pair with regard to  $C_4$  cycle  
[Kerala PMT 2011]

(a)	Primary $CO_2$ fixation product	-	PGA
(b)	Site of initial carboxylation	-	Mesophyll cells
(c)	Primary $CO_2$ acceptor	-	PEP
(d)	$C_4$ plant	-	Maize
(e)	Location of enzyme RuBisCO	-	Bundle sheath cells

27. CAM helps the plants in [CBSE PMT (Pre.) 2011]  
(a) Reproduction (b) Conserving water  
(c) Secondary growth (d) Disease resistance

28. Agranal chloroplasts occur in certain [MP PMT 1995, 98]  
Or

*Atriplex spongiosa* is a

- (a) Succulents (b)  $C_4$  plants  
(c) Hydrophytes (d)  $C_3$  plants
29. In the leaves of  $C_4$  plants, malic acid formation during  $CO_2$  fixation occurs in the cells of [CBSE PMT 2007, 08]  
(a) Mesophyll (b) Bundle Sheath  
(c) Phloem (d) Epidermis
30. Which of the following plants stand intermediate between  $C_3$  and  $C_4$  plants  
(a) *Triticum aestivum* (b) *Zea mays*  
(c) *Panicum milioides* (d) All the above
31. Chloroplasts without grana are known to occur in [KCET 2006]  
(a) Bundle sheath cells of  $C_3$  plants  
(b) Mesophyll cells of  $C_4$  plants  
(c) Bundle sheath cells of  $C_4$  plants  
(d) Mesophyll cells of all plants.
32. Which crop utilises solar energy most efficiently [BHU 2006]  
(a) Potato (b) Sugarcane  
(c) Wheat (d) Rice
33. In maximum plants stomata open during day and closed in night. Its exception is [Pb. PMT 2004; AMU (Med.) 2005]  
(a) Crassulacean acid metabolism plants  
(b)  $C_3$  plants  
(c)  $C_4$  plants  
(d) None of these



34. Correlation between 'Kranz' anatomy and  $C_4$  path of  $CO_2$  assimilation was first established by  
(a) Hill and Bendall (b) Calvin  
(c) Downton and Treguna (d) Arnold
35. The glycolate metabolism occur in  
[MP PMT 1995, 2000, 01; RPMT 1999; BHU 2001; AIIMS 2001; BVP 2003; WB JEE 2010]  
(a) Lysosomes (b) Ribosomes  
(c) Glyoxysomes (d) Peroxisomes
36. Members of family Crassulaceae perform [MHCET 2004]  
(a)  $C_3$  photosynthesis (b) CAM photosynthesis  
(c)  $C_4$  photosynthesis (d) All of the above
37. In Kranz anatomy, the bundle sheath cells have  
[CBSE PMT (Mains) 2011]  
(a) Thin walls, no intercellular spaces and several chloroplasts  
(b) Thick walls, many intercellular spaces and few chloroplasts  
(c) Thin walls, many intercellular spaces and no chloroplasts  
(d) Thick walls, no intercellular spaces and large number of chloroplasts
38. Source of  $CO_2$  for photosynthesis during day in CAM plant is  
[CPMT 2005]  
(a) 3-PGA (b) Malic acid  
(c) Oxalo-acetic acid (d) Pyruvate
39. Which of the following is a 4-carbon compound  
[Kerala PMT 2010]  
(a) Oxaloacetic acid (b) Phosphoglyceric acid  
(c) Ribulose bis phosphate (d) Phosphoenol pyruvate  
(e) Citric acid
40. Sugarcane show high efficiency of  $CO_2$  fixation because of  
[CPMT 2004]  
(a) Calvin cycle (b) Hatch and Slack cycle  
(c) TCA cycle (d) Greater sunlight
41. In  $C_4$ -plants, the carbon dioxide fixation occurs in  
[BHU 2004]  
(a) Guard cells (b) Spongy cells  
(c) Palisade cells (d) Bundle sheath cells
42. Photorespiration is favoured by  
[CBSE PMT 1991; BHU 2002; BVP 2003]  
(a) Low light and high  $O_2$   
(b) Low  $O_2$  and high  $CO_2$   
(c) Low temperature and high  $O_2$   
(d) High  $O_2$  and low  $CO_2$
43. Photosynthesis in  $C_4$  plants is relatively less limited by atmospheric  $CO_2$  levels because [CBSE PMT 2005]  
(a) Four carbon acids are the primary initial  $CO_2$  fixation products  
(b) The primary fixation of  $CO_2$  is mediated via PEP carboxylase  
(c) Effective pumping of  $CO_2$  into bundlesheath cells  
(d) Rubisco in  $C_4$  plants has higher affinity for  $CO_2$
44. Which of the following statements regarding  $C_4$  pathway is false [Kerala PMT 2010, 12]  
(a) The primary  $CO_2$  acceptor is 5 carbon molecule  
(b) The enzyme responsible for  $CO_2$  fixation is PEP case  
(c) The mesophyll cell lack RuBisCO enzyme  
(d) The  $C_4$  acid OAA is formed in the mesophyll cells  
(e) The bundle sheath cells contain the enzyme PEP case
45. CAM photosynthesis occurs in plants with [MP PMT 1993]  
(a) Thin green leaves with reticulate venation  
(b) Thin green leaves with parallel venation  
(c) Fleshy green leaves  
(d) Thin coloured leaves
46.  $C_4$  plant shows efficiency even in [HPMT 2005]  
(a) Low  $CO_2$  concentration (b) Low temperature  
(c) High  $O_2$  concentration (d) At low water
47. In sugarcane plant  $^{14}CO_2$  is fixed in malic acid, in which the enzyme that fixes  $CO_2$  is [CBSE PMT 1999]  
(a) Fructose phosphatase  
(b) Ribulose biphosphate carboxylase  
(c) Phosphoenol pyruvic acid carboxylase  
(d) Ribulose phosphate kinase
48. A process that makes important difference between  $C_3$  and  $C_4$  plants is [CBSE PMT (Pre.) 2012; NEET (Phase-II) 2016]  
(a) Transpiration (b) Glycolysis  
(c) Photosynthesis (d) Photorespiration
49. Which of the statements is not true of the  $C_4$  pathway [AIEEE Pharmacy 2004]  
(a) It requires more energy than the  $C_3$  pathway for production of glucose  
(b) It overcomes loss due to photorespiration  
(c) The  $CO_2$  acceptor is a  $C_3$  compound  
(d) It is inhibited by high  $CO_2$  concentration
50. Photorespiration is called [MHCET 2000; VITEEE 2006; J & K CET 2010]  
(a)  $C_2$  cycle (b)  $C_3$  cycle  
(c)  $C_4$  cycle (d) None of these
51. The first reaction in photorespiration is [RPMT 1999; CBSE PMT 2000; CPMT 2001]  
(a) Carboxylation  
(b) Decarboxylation  
(c) Oxygenation  
(d) Phosphorylation
52. In photorespiration glycolate is converted to  $CO_2$  and serine in [AIEEE Pharmacy 2003]  
(a) Chloroplasts (b) Peroxisomes  
(c) Vacuoles (d) Mitochondria
53. No. of carboxylation in  $C_4$  cycle is/are [DPMT 2003]  
(a) 1 (b) 2  
(c) 5 (d) 3

54. In Hatch and Slack pathway [BHU 2003]  
(a) Chloroplast are of same type  
(b) Occurs in Kranz anatomy where mesophyll have small chloroplast whereas bundle sheath have agranal chloroplast  
(c) Occurs in Kranz anatomy when mesophyll have small chloroplast where a bundle sheath have larger chloroplast  
(d) Kranz anatomy where mesophyll cell are diffused
55. The enzyme which catalyzes the photosynthetic  $C_4$  cycle is  
Or  
In  $C_4$  plants,  $CO_2$  combine with PEP in presence of  
(a) RuDP carboxylase (b) PEP carboxylase  
(c) Carbonic anhydrase (d) None of these
56. Peroxisomes are found in [Odisha JEE 2005]  
(a) Bundle sheath (b) Endosperm  
(c) Mesophyll cells (d) Vascular bundle
57. Peroxisome are related with [PUNE CET 1998; MP PMT 1998, 04, 05; AMU (Med.) 2005]  
(a) Photosynthesis (b) Photorespiration  
(c) Respiration (d) None
58. Photorespiration takes place is [BHU 1994, 2000, 01; MP PMT 2000, 01, 09; AIIMS 2001, 02; Kerala PMT 2002, 08; CPMT 2005; Odisha JEE 2011; CBSE PMT (Pre.) 2012]  
Or  
Photorespiratory reactions are operated in  
(a) Chloroplast, mitochondria  
(b) Mitochondria, peroxysome  
(c) Chloroplasts, peroxysome, mitochondria  
(d) Chloroplasts, cytoplasm, mitochondria
59. Which one is false about kranz anatomy [CPMT 2005]  
(a) Bundle sheath have large chloroplast and less developed grana  
(b) Mesophyll cells have large chloroplast and more  
(c) It is found in *Atriplex*, sugarcane, maize  
(d) Plant having it have better photosynthesizing power than  $C_3$  plants
60. The entire reactions of  $C_4$  pathway takes place in [WB JEE 2016]  
(a) Mesophyll and bundle sheath  
(b) Vascular bundle and palisade tissue  
(c) Mitochondria and peroxisome  
(d) Bundle sheath and endoplasmic reticulum
2. All life on earth derive its energy directly or indirectly from sun except [CBSE PMT 1994]  
(a) Mushroom and mould (b) Chemosynthetic bacteria  
(c) Symbiotic bacteria (d) Pathogenic bacteria
3. Which one of the following categories of organisms do not evolve oxygen during photosynthesis [CPMT 1999, 2003; JIPMER 1999; AIIMS 2004; RPMT 2006]  
(a) Red algae  
(b) Photosynthetic bacteria  
(c)  $C_4$  plants with Kranz anatomy  
(d) Blue green algae
4. The site of photosynthesis in blue green algae is [MP PMT 2009]  
Or  
Photosynthetic bacteria have pigments in [CBSE PMT 1999; RPMT 1999; Bihar CECE 2006]  
(a) Chromatophores (b) Mitochondria  
(c) Chloroplast (d) Root hair
5. In the bacterial photosynthesis, hydrogen donor is  
(a)  $H_2S$  (b)  $NH_2$   
(c)  $H_2O$  (d)  $H_2SO_4$
6. Which wavelength of light carry out photosynthesis in bacteria  
(a) Ultraviolet light (b) Blue  
(c) Red (d) Far red
7. *Leptothrix* is a  
(a) Nitrifying bacteria (b) Sulphur bacteria  
(c) Iron bacteria (d) Hydrogen bacteria
8. Green bacteria contains  
(a) Chlorobium chlorophyll-660  
(b) Chlorobium chlorophyll-650  
(c) Both (a) and (b)  
(d) Chlorobium chlorophyll-700
9. Bacterial photosynthesis takes place in [RPMT 1995]  
(a) Cytoplasm (b) Chromoplast  
(c) Chloroplast (d) Oxysome
10. Chlorophyll  $\alpha$  is absent in which of the following photosynthetic organism [BVP 2004]  
(a) Cyanobacteria (b) Red algae  
(c) Brown algae (d) Bacteria
11. Which of the following bacteria grow on isopropyl alcohol and convert it into acetone  
(a) Fermentative bacteria  
(b) Chemosynthetic bacteria  
(c) Photosynthetic purple non-sulphur bacteria  
(d) Nitrifying bacteria
12. Bacterial photosynthesis involves ..... [KCET 2004]  
(a) Both PS-I and PS-II (b) Either PS-I or PS-II  
(c) PS-I only (d) PS-II only

### Bacterial photosynthesis

1. Bacteria that uses chemical energy to fix  $CO_2$  are known as [Odisha JEE 2010]  
(a) Chemoautotroph (b) Photoautotroph  
(c) Heterotroph (d) None of these

13. Which of the following photosynthetic bacteria have both PS-I and PS-II

Or

Which was first photosynthetic organism [BVP 2004]

- (a) Green sulphur bacteria (b) Purple sulphur bacteria  
(c) Cyanobacteria (d) Purple non-sulphur bacteria

### Factors affecting photosynthesis

- Which of the following inhibits  $O_2$  release in light phase [DPMT 2004]  
(a) PMA (b) Zeatin  
(c) DCMU (d) None of these
- Which factor is not limiting in normal conditions for photosynthesis [MHCET 2003]  
(a) Air (b)  $CO_2$   
(c) Water (d) Chlorophyll
- Blackman's law of limiting factor is applied to [NCERT; RPMT 1999; AIIMS 2001]  
(a) Growth (b) Respiration  
(c) Transpiration (d) Photosynthesis
- The algae found in high temperature ponds are capable of doing photosynthesis upto  
(a)  $30^\circ C$  (b)  $75^\circ C$   
(c)  $90^\circ C$  (d)  $100^\circ C$
- What is called Warburg's effect on photosynthesis [MP PMT 2003]  
(a) Low rate of the process due to  $O_2$  supply  
(b) Low rate of the process due to  $CO_2$  supply  
(c) Both (a) and (b)  
(d) None of the above
- When  $NaHCO_3$  is added in small quantity in an experiment showing photosynthesis, what will be the effect on it  
(a) Rate will be lowered (b) Rate will be increased  
(c) Rate will be normal (d) Process will stop
- The most effective wavelength of visible light in photosynthesis is in the region of [CBSE PMT 1999; RPMT 1999; CPMT 2000, 10; MP PMT 2000, 10, 11; Kerala CET 2003; AFMC 2003; DPMT 2004]  
(a) Violet (b) Green  
(c) Yellow (d) Red
- Compensation point is [CPMT 1998, 99; AFMC 2002]  
(a) Where there is neither photosynthesis nor respiration  
(b) When rate of photosynthesis is equal to the rate of respiration  
(c) When entire food synthesized into photosynthesis remain utilized  
(d) When there is enough water just to meet the requirements of plant

9. Which one of the following is not a limiting factor for photosynthesis [KCET 1999]

- (a) Oxygen (b) Carbon dioxide  
(c) Chlorophyll (d) Light

10. If the rate of translocation of food is slow, what will be the effect on photosynthesis

- (a) It will increase (b) It will remain same  
(c) Becomes double (d) It will decrease

11. Which of the following wavelength of light is absorbed maximum for photosynthesis

Or

Chl. a absorb's max of [MP PMT 2005]

- (a) Red light (b) Blue light  
(c) Green light (d) Yellow light

12. In which of the following the rate of photosynthesis is decreased and is known as red drop [MP PMT 1992]

- (a) Blue light  
(b) Green light  
(c) Red light more than 680 nm  
(d) Red light less than 680 nm

13.  $Q_{10}$  refers to [RPMT 1997]

- (a) Quality quotient (b) Temperature quotient  
(c) Respiratory quotient (d) Quantum constant

14. A plant is kept in 300ppm  $CO_2$  concentration, what will happen to it

- (a) Plant will die soon  
(b) Plant will grow but will not die  
(c) Plant will show normal photosynthesis  
(d) Respiration will be greatly decreased

15. What will be the effect of intermittent light on photosynthesis

- (a) It will increase (b) It will decrease  
(c) Will not be effected (d) Process will stop

16. What will be the effect when very high intensity of light is supplied to a photosynthesis system

- (a) Process will increase  
(b) Process will decrease  
(c) Process will stop due to solarization  
(d) None of the above

17. Which of the following conditions are favourable for cyclic photophosphorylation [CPMT 1999]

- (a) Anaerobic condition  
(b) Aerobic and optimum light  
(c) Aerobic and low light intensity  
(d) Anaerobic and low light intensity

18. Plants which can photosynthesize at as low temperature (upto  $-35^\circ C$ ) are

- (a) Conifers (b) Blue-green algae  
(c) Xerophytes (d) Tropical plants



19. When a photosynthetic plant is transferred to an atmosphere of enriched  $O_2$ , its rate of
  - (a) Photosynthesis would increase
  - (b) Photosynthesis would decrease
  - (c) Respiration would decrease
  - (d) Osmosis would increase
20. Under conditions of constant illumination, the compensation period for a whole aquarium would be of infinite length when
  - (a) The biomass of animals equals the biomass of plants
  - (b) The respiratory exchanges of the animals are equal to the photosynthetic exchanges of the plants
  - (c) The oxygen intake of the animals equals of oxygen output of photosynthesis
  - (d) The carbon dioxide output of the animals and plants equals to the photosynthetic intake of the plants
21. In nature the photosynthesis should proceed upto the limit of
  - (a) Light
  - (b) Temperature
  - (c)  $CO_2$
  - (d) Moisture and wind
22. Which of the following would happen if the supply of  $O_2$  is decreased to an illuminated wheat plant
  - (a) Its photosynthesis would decrease
  - (b) Its respiration would increase
  - (c) Its photosynthesis would increase
  - (d) All the physiological process would stop
23. With reference to factors affecting the rate of photosynthesis, which of the following statements is **not correct** [NEET 2017]
  - (a) Light saturation for  $CO_2$  fixation occurs at 10% of full sunlight
  - (b) Increasing atmospheric  $CO_2$  concentration up to 0.05% can enhance  $CO_2$  fixation rate
  - (c)  $C_3$  plants respond to higher temperatures with enhanced photosynthesis while  $C_4$  plants have much lower temperature optimum
  - (d) Tomato is a greenhouse crop which can be grown in  $CO_2$  enriched atmosphere for higher yield
5. During light reaction in photosynthesis the following are formed [NCERT]
  - (a) ATP and sugar
  - (b) Hydrogen,  $O_2$  and sugar
  - (c) ATP, hydrogen donor and  $O_2$
  - (d) ATP, hydrogen and  $O_2$  donor
6. Dark reaction in photosynthesis is called so because [NCERT]
  - (a) It can occur in dark also
  - (b) It does not depend on light energy
  - (c) It cannot occur during day light
  - (d) It occurs more rapidly at night
7. When  $CO_2$  is added to PEP, the first stable product synthesized is [NCERT]
  - (a) Pyruvate
  - (b) Glyceraldehyde-3-phosphate
  - (c) Phosphoglycerate
  - (d) Oxaloacetate
8. Splitting of water is associated with [NCERT]
  - (a) Photosystem I
  - (b) Lumen of thylakoid
  - (c) Both Photosystem I and II
  - (d) Inner surface of thylakoid membrane
9. The correct sequence of flow of electrons in the light reaction is [NCERT]
  - (a) PSII, plastoquinone, cytochromes, PSI, ferredoxin
  - (b) PSI, plastoquinone, cytochromes, PSII, ferredoxin
  - (c) PSI, ferredoxin, PSII
  - (d) PSI, plastoquinone, cytochromes, PSII, ferredoxin
10. The enzyme that is not found in a  $C_3$  plant is [NCERT]
  - (a) RuBP Carboxylase
  - (b) PEP Carboxylase
  - (c) NADP reductase
  - (d) ATP synthase
11. The reaction that is responsible for the primary fixation of  $CO_2$  is catalysed by [NCERT]
  - (a) RuBP carboxylase
  - (b) PEP carboxylase
  - (c) RuBP carboxylase and PEP carboxylase
  - (d) PGA synthase



NCERT

### Exemplar Questions

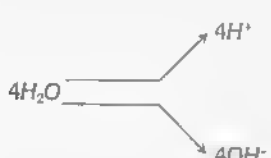
1. Which metal ion is a constituent of chlorophyll [NCERT]
  - (a) Iron
  - (b) Copper
  - (c) Magnesium
  - (d) Zinc
2. Which pigment acts directly to convert light energy to chemical energy [NCERT]
  - (a) Chlorophyll a
  - (b) Chlorophyll b
  - (c) Xanthophyll
  - (d) Carotenoid
3. Chemosynthetic bacteria obtain energy from [NCERT]
  - (a) Sun
  - (b) Infra red rays
  - (c) Organic substance
  - (d) Inorganic chemicals
4. Energy required for ATP synthesis in PSII comes from [NCERT]
  - (a) Proton gradient
  - (b) Electron gradient
  - (c) Reduction of glucose
  - (d) Oxidation of glucose



### Critical Thinking

#### Objective Questions

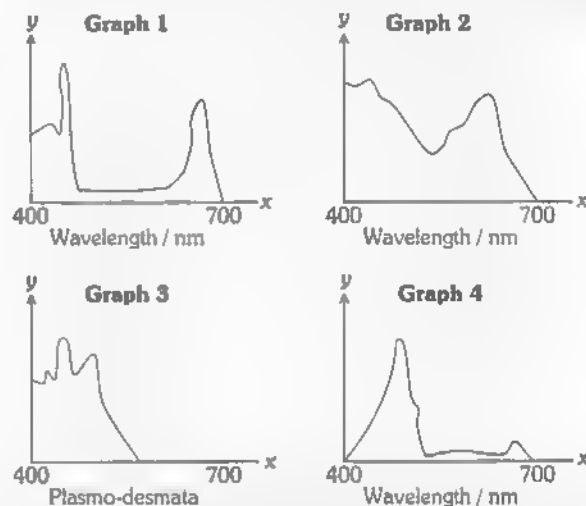
1. Which is the evidence to show that  $O_2$  is released in photosynthesis comes from water
  - (a) Isotopic  $O_2$  supplied as  $H_2O$  appears in the  $O_2$  released in photosynthesis
  - (b) Isolated chloroplast in water releases  $O_2$  if supplied potassium ferrocyanide or some other reducing agent
  - (c) Photosynthetic bacteria use  $H_2S$  and  $CO_2$  to make carbohydrates
  - (d) All the above

2. What effect would occur on photosynthesis, if the amount of oxygen in the atmosphere decreases [RPMT 1997]
- Increase in  $C_3$  cycle and decrease in  $C_4$  cycle
  - Increase in  $C_4$  cycle and decrease in  $C_3$  cycle
  - Increase in  $C_3$  cycle and no change in  $C_4$  cycle
  - Increase in  $C_4$  cycle and no change in  $C_3$  cycle
3. Read the following four statements (A-D)
- Both, photophosphorylation and oxidative phosphorylation involve uphill transport of protons across the membrane
  - In dicot stems, a new cambium originates from cells of pericycle at the time of secondary growth
  - Stamens in flowers of *Gloriosa* and *Petunia* are polyandrous
  - Symbiotic nitrogen-fixers occur in free-living state also in soil
- How many of the above statements are right [CBSE PMT (Mains) 2012]
- Two
  - Three
  - Four
  - One
4. Which of the following may show photosynthesis in moonlight
- Some thermal algae
  - Some marine algae
  - Some fresh water algae
  - None of the above
- 5.
- 
- In this process which of the following play important role [GUJCET 2015; MHCET 2015]
- Chlorophyll
  - Light energy
  - $Ca^{++}, Mn^{++}, Cl^{-}$
  - All of the above
6. Chloroplast contains maximum quantity of [BCECE 2005, 06]
- Pyruvic carboxylase
  - Hexokinase
  - RuBP carboxylase
  - None of the above
7. What is common between photosynthesis and respiration [MP PMT 1993, 96, 2003, 06; BHU 1995; AFMC 1995; Haryana PMT 2005; MH CET 2005; DPMT 2006; KCET 2006]
- Cytochrome
  - Light
  - $H_2O$
  - Temperature
8. Photosynthesis is [NCERT; MH CET 2002; Odisha JEE 2012; MP PMT 2013]
- Oxidative, exergonic, catabolic
  - Reductive, endergonic, anabolic
  - Reductive, exergonic, anabolic
  - Reductive, endergonic, catabolic
9. Which of the following can photosynthesize at low temperature ( $-20^{\circ}C$ ) [BVP 2000]
- Bacteria
  - Lichen
  - Yeast
  - Batrachospermum*
10. The electron transport chain of photosynthetic process is [JIPMER 2002]
- In the stroma of the chloroplast
  - Bound to the thylakoid membranes
  - Present in the outer membrane of the chloroplast
  - Present in mitochondria
11. What percentage of usable radiant energy entering a reaction site of photosynthesis is converted to potential energy [BHU 2002]
- 10%
  - 20%
  - 35%
  - 42%
12. Chlorophyll 'a' is found in [CBSE PMT 1992]
- All oxygen releasing photosynthetic forms
  - All plants except fungi
  - All higher plants that photosynthesize
  - All photosynthetic prokaryotes and eukaryotes
13. The empirical formula for chlorophyll 'a' is [KCET 1994, 2000; AFMC 1994; Wardha 2005; J & K CET 2008; WB JEE 2016]
- $C_{35}H_{72}O_5N_4Mg$
  - $C_{55}H_{70}O_6N_4Mg$
  - $C_{55}H_{72}O_5N_4Mg$
  - $C_{54}H_{70}O_6N_4Mg$
14. Which of the following is wrongly matched [Kerala PMT 2010]
- Sorghum - Kranz Anatomy
  - PEP carboxylase - Mesophyll cells
  - Blackman - Law of limiting factors
  - Photorespiration -  $C_3$  plants
  - PS II - P700
15. Chlorophyll 'a' molecule at its carbon atom 3 of the pyrrole ring II has one of the following [CBSE PMT 1996, 97]
- Aldehyde group
  - Methyl group
  - Carboxylic group
  - Magnesium
16. Bacteriochlorophyll differs from chlorophyll 'a' in having
- One pyrrole ring with one hydrogen
  - One pyrrole ring with two hydrogen
  - One pyrrole ring with three hydrogen
  - One pyrrole ring with four hydrogen
17. In photosynthesis, photolysis of water is used in [CPMT 1998]
- Reduction of NADP
  - Oxidation of NADP
  - Oxidation of FAD
  - None of these

18.  $C_4$  plants are found among  
 (a) Gramineae only (b) Monocots only  
 (c) Dicots only (d) Monocots as well as dicots
19. Energy transfer in photosynthesis occurs as (BHU 2003)  
 (a) Phycoerythrin  $\rightarrow$  Phycocyanin  $\rightarrow$  Carotenoid  $\rightarrow$  Chlorophyll *a*  
 (b) Chlorophyll *b*  $\rightarrow$  Carotenoid  $\rightarrow$  Phycoerythrin  $\rightarrow$  Chlorophyll *a*  
 (c) Phycocyanin  $\rightarrow$  Phycoerythrin  $\rightarrow$  Carotenoid  $\rightarrow$  Chlorophyll *a*  
 (d) Chlorophyll  $\rightarrow$  Carotenoid  $\rightarrow$  Phycocyanin  $\rightarrow$  Chlorophyll *a*
20. Photosynthesis consists of essentially two biological reaction systems, one followed by the other, the second of these systems does which of the following  
 (a) Fixes  $CO_2$   
 (b) Traps light energy  
 (c) Synthesizes starch  
 (d) Works only in the presence of light
21. During dark reaction for fixation of carbon, the three carbon atoms of each molecule of 3-phosphoglyceric acid (PGA) are derived from (BHU 1994)  
 (a) RuBP only (b)  $CO_2$  only  
 (c) RuBP +  $CO_2$  (d) RuBP +  $CO_2$  + PEP
22. Calvin's cycle is found in (RPMT 1997)  
 (a) Only  $C_3$  plants (b) Only photohilloidous plants  
 (c) All  $C_4$  plants (d) All photosynthetic plants
23. The first Intermediate formed during photosynthesis is (CPMT 2000)  
 (a) Fructose 1, 6-diphosphate  
 (b) Ribulose 1, 5-biphosphate  
 (c) Xylulose-5-phosphate  
 (d) Phosphoglyceraldehyde
24. First transitory chemical formed by reaction between  $CO_2$  and RuBP is (J & K CET 2002)  
 (a) PGAL/GAP  
 (b) 2-Carboxy, 3- keto, 1-5-biphospho ribitol  
 (c) PGA  
 (d) Dihydroxy acetone phosphate
25. As compared to a  $C_3$  plant, how many additional molecules of ATP are needed for net production of one molecule hexose sugar by  $C_4$  plants (CBSE PMT 2005)  
 (a) Two (b) Six  
 (c) Zero (d) Twelve

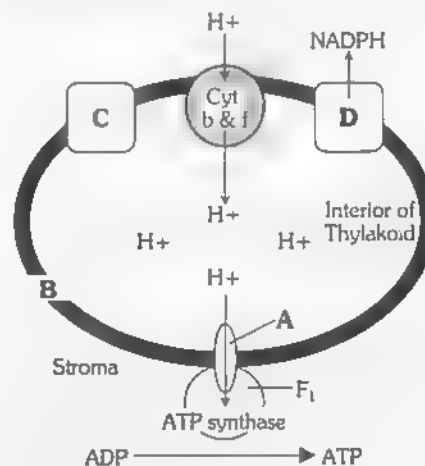
26. Three of the graphs below show the absorption spectra of photosynthetic pigments. One graph shows the action spectrum of photosynthesis for a plant containing the pigments.

All the x axis show wavelength. Three of the y axis show light absorption. One y axis shows the rate of photosynthesis [NCERT]



	Chlorophyll <i>a</i>	Absorption Chlorophyll <i>b</i>	Spectra Carotenoids	Action spectrum
(a)	3	2	4	1
(b)	2	4	3	1
(c)	2	1	3	4
(d)	1	4	3	2

27. Observe the pathway of ATP synthesis through chemiosmosis given below



Select the right answer in which correct words for all the four blanks A, B, C and D are indicated [NCERT]

- (a) A -  $F_0$ , B - Thylakoid membrane, C - Photosystem (II), D - Photosystem (I)  
 (b) A -  $F_1$ , B - Thylakoid membrane, C - Photosystem (II), D - Photosystem (I)  
 (c) A -  $F_0$ , B - Thylakoid membrane, C - Photosystem (I), D - Photosystem (II)  
 (d) A -  $F_1$ , B - Thylakoid membrane, C - Photosystem (I), D - Photosystem (II)

28. Chromatophores take part in [AIPMT 2015]  
 (a) Growth (b) Movement  
 (c) Respiration (d) Photosynthesis
29. In a chloroplast the highest number of protons are found in [NEET (Phase-I) 2016]  
 (a) Stroma  
 (b) Lumen of thylakoids  
 (c) Inter membrane space  
 (d) Antennae complex
30. Photosynthesis cannot be operated in [WB JEE 2016]  
 (a) Red light (b) Yellow light  
 (c) Green light (d) Blue light

## Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

- (a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion  
 (b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion  
 (c) If the assertion is true but the reason is false  
 (d) If both the assertion and reason are false  
 (e) If the assertion is false but reason is true

1. Assertion :  $C_4$  pathway of  $CO_2$  fixation is found in some tropical plants.  
 Reason : In this pathway  $CO_2$  is fixed by 3C compound. [AIIMS 1998]
2. Assertion : Six molecules of  $CO_2$  and twelve molecules of  $NADPH^+ + H^+$  and 18 ATP are used to form one hexose molecule.  
 Reason : Light reaction results in formation of ATP and  $NADPH_2$  [AIIMS 2002]
3. Assertion : Rhoeo leaves contain anthocyanin pigments in epidermal cells.  
 Reason : Anthocyanins are accessory photosynthetic pigments. [AIIMS 2003]
4. Assertion : There is a decrease in photosynthesis, if the photosynthetic cells are illuminated by light of  $P_{680}$  nm or more wavelength.  
 Reason : In red drop phenomenon the rate of photosynthesis decreases.
5. Assertion : The concentration of  $O_2$  in the atmosphere is inhibitory to photosynthesis  
 Reason : Oxygen inhibitory effect is due to Warburg effect.

6. Assertion :  $C_4$  photosynthetic pathway is more efficient than the  $C_3$  pathway.  
 Reason : Photorespiration is suppressed in  $C_4$  plants.
7. Assertion : CAM plants lack structural compartmentation of leaf, as found in  $C_4$  plants.  
 Reason : Stomata of CAM plants are open during the day.
8. Assertion : Plants utilizing first RuBP in  $CO_2$  fixations are called  $C_3$  plants.  
 Reason : Plants utilizing first PEP in  $CO_2$  fixations are called  $C_4$  plants.
9. Assertion : Cyclic pathway of photosynthesis first appeared in some eubacterial species.  
 Reason : Oxygen started accumulating in the atmosphere after the non-cyclic pathway of photosynthesis evolved. [AIIMS 2004, 07]
10. Assertion : The stromal thylakoids are rich in both PS I and PS II.  
 Reason : The granal membranes are rich in ATP synthetase.
11. Assertion : Cyclic photophosphorylation synthesizes ATP.  
 Reason : ATP synthesize in cyclic photophosphorylation is not associated with NADPH formation.
12. Assertion : Oxidative phosphorylation requires oxygen.  
 Reason : Oxidative photophosphorylation occurs in mitochondria.
13. Assertion : Each molecule of ribulose-1, 5-biphosphate fixes one molecule of  $CO_2$ .  
 Reason : Three molecules of NADPH and two ATP are required for fixation of one molecule of  $CO_2$ .
14. Assertion :  $CO_2$  is transported from mesophyll cells to bundle sheath of chloroplasts in  $C_4$  plants.  
 Reason : RuBP is called final acceptor of  $CO_2$  in  $C_4$  plants.
15. Assertion : One molecule of  $CO_2$  is fixed to give 686 kcal in photosynthesis.  
 Reason : To form a hexose, six molecules of  $CO_2$  are fixed.
16. Assertion : In the formation of one glucose, 686,000 calories energy are produced.  
 Reason : The energy is provided by a total of 12 NADPH and 18 ATP.
17. Assertion : Sciophytes require higher light intensity than heliophytes.  
 Reason : Sciophytes grow below the canopy of trees.
18. Assertion : Plants utilize 5-10% of the absorbed water in photosynthesis.  
 Reason : Reduced leaf hydration decrease the photosynthesis.

# Answers

## History of photosynthesis

1	a	2	b	3	c	4	a	5	a
6	b	7	d	8	d	9	d	10	b
11	d	12	c	13	a	14	c	15	a
16	b								

## Experiments

1	b	2	d	3	a	4	a	5	d
6	b	7	b	8	d	9	b	10	a
11	a	12	b	13	c				

## Photosynthetic apparatus

1	a	2	b	3	d	4	b	5	b
6	e	7	b	8	a	9	b	10	d
11	c	12	d	13	b	14	e	15	c
16	d	17	b	18	d	19	b	20	b
21	c	22	b	23	d	24	d	25	a
26	a	27	a	28	a	29	a	30	b
31	d	32	b	33	d	34	c	35	b
36	b	37	d						

## Light reaction/Pigments

1	c	2	a	3	b	4	c	5	b
6	a	7	b	8	a	9	b	10	d
11	a	12	c	13	d	14	a	15	b
16	b	17	c	18	d	19	b	20	a
21	d	22	b	23	b	24	d	25	d
26	a	27	a	28	c	29	c	30	b
31	a	32	b	33	b	34	d	35	a
36	d	37	c	38	c	39	c	40	c
41	a	42	a	43	a	44	c	45	a
46	c	47	c	48	d	49	c	50	b

51	b	52	c	53	a	54	c	55	c
56	a	57	a	58	a	59	d	60	c
61	a	62	c	63	c	64	c	65	a
66	b	67	d	68	d	69	b	70	b
71	a	72	b	73	d	74	a	75	d
76	b	77	b	78	a	79	c	80	b
81	c	82	c	83	b	84	b	85	c

## Dark reaction

1	c	2	a	3	a	4	c	5	d
6	c	7	d	8	b	9	d	10	d
11	b	12	c	13	a	14	b	15	b
16	a	17	b	18	a	19	a	20	d
21	c	22	b	23	b	24	c	25	c
26	c	27	a	28	d	29	c	30	b
31	b	32	b						

## C<sub>4</sub>/CAM/Photorespiration

1	d	2	d	3	b	4	d	5	b
6	b	7	c	8	c	9	a	10	d
11	d	12	b	13	d	14	d	15	a
16	b	17	d	18	a	19	b	20	c
21	b	22	a	23	d	24	b	25	b
26	a	27	b	28	b	29	a	30	c
31	c	32	b	33	a	34	c	35	d
36	b	37	d	38	b	39	a	40	b
41	d	42	d	43	b	44	a, e	45	c
46	a	47	c	48	d	49	c	50	a
51	c	52	d	53	b	54	b	55	b
56	c	57	b	58	c	59	b	60	a

## Bacterial photosynthesis

1	a	2	b	3	b	4	a	5	a
6	d	7	c	8	c	9	a	10	d
11	c	12	c	13	c				



## Factors affecting photosynthesis

1	c	2	d	3	d	4	b	5	a
6	b	7	d	8	b	9	a	10	d
11	b	12	c	13	b	14	c	15	a
16	c	17	d	18	a	19	b	20	d
21	b	22	c	23	c				

## NCERT Exemplar Questions

1	c	2	a	3	d	4	a	5	c
6	a	7	d	8	d	9	a	10	b
11	c								

## Critical Thinking Questions

1	d	2	c	3	a	4	b	5	d
6	c	7	a	8	b	9	b	10	b
11	c	12	a	13	c	14	a	15	b
16	b	17	a	18	d	19	c	20	a
21	c	22	d	23	d	24	b	25	d
26	d	27	a	28	d	29	b	30	c

## Assertion and Reason

1	b	2	b	3	c	4	b	5	a
6	a	7	c	8	b	9	b	10	d
11	b	12	b	13	c	14	a	15	a
16	a	17	a	18	a				

# Answers and Solutions

## History of photosynthesis

- (a) Blackman propounded the law of limiting factors. He also proposed the occurrence of a dark phase in photosynthesis.
- (c) The discovery of Emerson effect. One group of pigments absorbs light of both shorter and longer wavelengths (more than 680nm) and another group of pigment absorbs light of only shorter wavelengths (less than 680nm). These two groups of pigments are known as pigment systems or photosystems.

- (a) Malvin Calvin (1954) traced the pathway of carbon in photosynthesis and gave the  $C_3$  cycle, (now known after him as calvin cycle). He was awarded Nobel prize for this work in 1960.
- (a) Malvin calvin and his coworkers in 1954 by using the methods of radio active tracer technique, chromatography and Autoradiography.
- (b) Arnon et al. (1954) first of all demonstrated that isolated chloroplasts can produce ATP from ADP+ip and they called this ATP production as photophosphorylation.
- (d) Pelletier and Caventou (1818) discovered chlorophyll. It could be separated from leaf by boiling in alcohol.
- (d) Robert Mayer (1845) proposed that light has radiant energy and this radiant energy is converted into chemical energy by plants, which serves to maintain life of the plants and also animals.
- (d) Thylakoids (Menke, 1961) or baggy trousers are structural elements of chloroplast.
- (b) According to Jan Ingen-Housz (1779), both green parts and sunlight are required for air purification and plant nourishment.
- (d) Bousingault (1860) reported that amount of  $O_2$  evolved in photosynthesis is equal to amount of  $CO_2$  absorbed and both these processes occur simultaneously as soon as light is given.
- (c) Helmont concluded that "all food of the plant is derived from rain water and not from soil and all parts of the plant develop from water".
- (c) Hatch and Slack (1965) discovered the  $C_4$  pathway for  $CO_2$  fixation in certain tropical grasses.
- (a) In 1930 C.B. Van Niel proved that, sulphur bacteria use  $H_2S$  (in place of water) and  $CO_2$  to synthesize carbohydrates as follows :
 
$$6CO_2 + 12H_2S \longrightarrow C_6H_{12}O_6 + 6H_2O + 12S$$
 This led Van Niel to the pastulation that in green plants, water ( $H_2O$ ) is utilized in place of  $H_2S$  and  $O_2$  is evolved in place of sulphur (S). He indicated that water is electron donar in photosynthesis.
 
$$6CO_2 + 12H_2O \longrightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$$

## Experiments

- (d) Both blue and red wavelength are affective because the amount of oxygen released was found to be maximum in blue and red absorption bands of the chlorophyll.
- (a) During photosynthesis  $O_2$  evolved by the hydrolysis of water. If  $H_2O^{18}$  is used in 'A' plant then it become true that  $O^{18}$  type oxygen evolved from 'A' plant during photosynthesis.

4. (a)  $C^{14}$  isotope used for knowing carbon path and  $O^{18}$  used for verified that source of  $O_2$  in photosynthesis is  $H_2O$ , not  $CO_2$ .
6. (b) Ruben and Kamen used  $C^{14}$  radioactive isotopes in *chlorella* for knowing path of carbon in photosynthesis.
9. (b) Calvin traced the path in photosynthesis associated with dark reaction. Radioactive isotope of carbon ( $C^{14}$ ) is used, it is observed that ( $C^{14}O_2$ ) reduction of  $CO_2$  is definitely in dark reaction.
10. (a) Calvin used isotopes  $C^{14}$  in *chlorella* for knowing carbon path in photosynthesis. *Chlorella* is a unicellular alga is using by Ruben Kamen and warburg. Because algae carry out 90% of photosynthesis.
11. (a) Photolysis occur in presence of light quanta and requires  $Mn^{++}$  and  $Cl^-$  ions as catalyst for water oxidising.
 
$$4H_2O \xrightarrow{Mn^{++}Cl^-} 4(OH)^- + 4H^+$$
 Then  $H$  radicle forms water and  $O_2$  as a by product
 
$$4OH^- \longrightarrow 2H_2O + O_2 \uparrow$$
12. (b) Emerson and Arnold proved the existence of light and dark reaction by flashing of light experiment in photosynthesis.
9. (b) Photosynthesis reaction shows that "formation of carbohydrates from  $CO_2$  and  $H_2O$  by illuminated green cells of plants,  $O_2$  and  $H_2O$  are the bye products.
15. (c) 90% of total photosynthesis is carried out by aquatic plants, chiefly algae (80% in oceans and 10% in fresh water). 10% of total photosynthesis is performed by land plants.
17. (b) ATP is formed during photophosphorylation after this reaction  $NADPH_2$  and ATP move in dark reaction it is known as assimilatory power.
19. (b)  $CO_2 + 2H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light energy}} (CH_2O)_n + H_2O + O_2 \uparrow$
22. (b) Rubisco constitutes 16% of chloroplast protein. It is the most abundant protein on this planet.
23. (d) Only 1-4% light is utilized in photosynthesis. In general rate of photosynthesis is more in intense light than diffused light.
24. (d) Photosynthesis is an oxidation reduction process where  $H_2O$  is oxidized by photolysis into  $O_2$  and  $CO_2$  is reduced into carbohydrates
26. (a) Arnon (1956) used the term 'Assimilatory powers' for ATP and  $NADPH_2$ . ( $NADPH_2$  alone is called reducing power).
29. (a) Sugarcane is  $C_4$  plant. The chloroplasts in  $C_4$  leaves are dimorphic (Two morphologically distinct types). The chloroplasts of bundle sheath cells contain starch grains but lack grana. The mesophyll cells on the other hand, contain normal type of chloroplasts.
32. (b) Because  $CO_2$  is utilized in photosynthesis process by plants.
34. (c) Burning of sugar, respiration in plants and heating of limestone is responsible for the liberation of  $CO_2$  but in photosynthesis green plants take in  $CO_2$  and release  $O_2$  thus purifying the air.
35. (b) Park and Biggins (1964) gave the term quantasome for photosynthetic units is equivalent to 230 chlorophyll molecules.
36. (b) ATP (adenosine triphosphate) is called energy currency of cells. ATP is energy rich compound where energy is present in terminal pyrophosphate bonds.
37. (d) Light, chlorophyll,  $CO_2$  and water all are essential in photosynthesis. In photosynthesis process energy rich compounds like carbohydrates are synthesized from simple inorganic compounds like carbon dioxide and water in the presence of chlorophyll and sunlight with liberation of  $O_2$ .

### Photosynthetic apparatus

1. (a) In Etiolation, chlorophyll (green) converts in protochlorophyll (yellow) in dark, etiolin hormone is formed due to which plants become elongated.
 
$$\begin{array}{ccc} \text{Chlorophyll} & \xrightleftharpoons[\text{Light}]{\text{Dark}} & \text{Protochlorophyll} + 2H \\ (\text{green}) & & (\text{yellow}) \end{array}$$
2. (b) Photosynthesis by plants is most vital process for the existence of life on earth because photosynthesis helps to maintain the equilibrium position of  $O_2$  and  $CO_2$  in the atmosphere. It purifies the air and synthesize food for all living beings.
4. (b)  $6CO_2 + 12H_2O \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} C_6H_{12}O_6 + 6O_2 + 6H_2O$ .
5. (b) When photon of light energy falls on chlorophyll molecule, one of the electrons pair from ground or singlet state passes into higher energy level called excited singlet state.
7. (b) The main function of chloroplast is photosynthesis, in which radiant energy of sun is converted into chemical form of energy (ATP), which is utilized by all living organisms to perform their life activities.
8. (a) The addition of phosphate group to ADP and AMP called phosphorylation.
 
$$ADP + iP \longrightarrow ATP$$
 By this process ATP is formed which is used in dark reaction.

### Light reaction/Pigments

1. (c) The splitting of water during photosynthesis is called photolysis.  $Mn$  and  $Cl$  plays important role in photosynthesis specially light reaction of photosynthesis in splitting of water.
7. (b) Chlorophyll-a is widely distributed in green plant and it is also called primary photosynthetic pigment and universal photosynthetic pigment.

8. (a) The chloroplast pigment are fat soluble and are located in the lipid part of the thylakoid membranes.
10. (d) Xanthophylls are yellow coloured carotenoid also called Xanthols or carotenols.
12. (c) Wavelength occur in red part of the spectrum is 650-760 nm.
33. (b) Non cyclic photophosphorylation involved both PS-I and PS-II. Flow of electrons is unidirectional. Here electrons are not cycled back and are used in the reduction of NADP to NADPH<sub>2</sub>.
37. (c) Chl.-a 700 or P<sub>700</sub> is the reaction centre of PS-I.
38. (c) The colours of leaves is modified in certain plants due to the presence of purple pigment called anthocyanins. Anthocyanins are soluble in water, hence they occur in solution in the water of the cells.
41. (a) Chlorophyll a is widely distributed in green algae and higher plants.
49. (c) During light reaction energy from sunlight is absorbed and converted into chemical energy which is stored in ATP and NADPH + H<sup>+</sup>.
50. (b) Core metal of chlorophyll is Mg. When central Mg is replaced by Fe, the chlorophyll becomes a green pigment called "cytochrome" which is used in photosynthesis.
52. (c) Phosphate is coupled with ADP to produce ATP using light energy during photosynthesis
53. (a) Cytochromes are systems of electron-transferring proteins, with iron-porphyrin or copper-porphyrin as prosthetic groups.
55. (c) Photolysis means splitting of water molecules to release oxygen. This occurs in photosynthesis, i.e., Photosystem-II.
56. (a) Chlorophyll is soluble in organic solvents like alcohol, acetone etc.
57. (a) Green plants and algae use two types of photosystems, PS-I with chl. P<sub>700</sub> in its reaction centre and PS-II with P<sub>680</sub> in its reaction centre. The two photosystems are linked by a chain of electron carriers. Light excites P<sub>680</sub> of PS-II to activated P<sub>680</sub>.
58. (a) This non-cyclic photophosphorylation is also known as Z-Scheme (because of shape of path of electron - flow) and this was given by Hill and Bendall (1960).
61. (a) The reaction centers of PS-I and PS-II can be denoted as P<sub>700</sub><sup>+</sup> and P<sub>680</sub><sup>+</sup> respectively. Positively charged reaction centers act as attractants for electrons.
63. (c) The important pigments of this system are chlorophyll a 670, chlorophyll a 683, chlorophyll a 695, P<sub>700</sub>. Some physiologist also include carotenes and chlorophyll b in pigment system I. P<sub>700</sub> act as the reaction centre.
64. (c) Light energy brings about changes in Mn (Mn<sup>2+</sup>, Mn<sup>3+</sup>, Mn<sup>4+</sup>) which helps in removing electrons from OH<sup>-</sup> component of water forming oxygen.
65. (a) Robert Hill (1939) first of all showed that if chloroplasts extracted from leaves of *stellaria media* and *Lamium album* are suspended in a test tube containing suitable electron acceptor e.g., potassium ferrooxalate and potassium ferricyanide, O<sub>2</sub> is released due to photochemical splitting of water.
69. (b) During light reaction not only reduced NADP is formed and O<sub>2</sub> is evolved but ATP is also formed. This formation of high energy phosphates (ATP) is dependent on light hence called photophosphorylation.
71. (a) Non cyclic photophosphorylation involves both PS-I and PS-II. The process begins with the absorption of light energy by PS-II. As light energy is absorbed, 4e<sup>-</sup> become excited from chlorophyll -a at the reaction centre. The 4e<sup>-</sup> released by these molecules are accepted by an electron - acceptor - substance. The other effect of this event is that photolysis of water is induced. The chlorophyll-a molecules in PS-II act as strong oxidising agent. As described earlier, 4 molecules of H<sub>2</sub>O are thus decomposed through light-induced-energy. The 4H<sup>+</sup> ions become associated with 2 NADP. The 4 OH<sup>-</sup> ions are associated with the release of oxygen. The four electrons (4e<sup>-</sup>) released from 4 OH<sup>-</sup> are received by chlorophyll-a molecules at reaction-centre of PS-II.
72. (b) The photosystem-II (Reaction centre of P-680) extracts an e<sup>-</sup> from water returning to its unexcited state. The removal of four e<sup>-</sup> from two molecules of water requires 4 quanta of light to fall on PS-II and leads to the production of 4H<sup>+</sup> ions and one molecule of O<sub>2</sub>.
79. (c) The absorption spectrum of chlorophyll a and chlorophyll b indicate that these pigments mainly absorb blue and red lights. Action spectrum shows that maximum photosynthesis takes place in blue and red regions of spectrum.
80. (b) The figure denotes non-cyclic photophosphorylations that involves both PS-I (reaction centre-700) and PS-II (reaction centre-680). The electrons released from PS II is not cycled back but is transported to PS-I through a series of chemical compounds. Before reaching PS-I, the electrons pass through plastocyanin.

### Dark reaction

1. (c) Dark reaction was first of all established by Blackman that's why it is called Blackman's reaction.

7. (d) Dark reaction takes place in bundle sheath (because RuBISCO present in stroma of chloroplast of bundle sheath).
12. (c) A- Fixation of  $\text{CO}_2$  by PEPCO  
B- Decarboxylation  
C- Regeneration
13. (a) Ribulose 1, 5-diphosphate carboxylase enzyme is first enzyme of Calvin cycle convert Ribulose-1, 5 diphosphate into 3-phosphoglyceric acid.
14. (b) During photosynthesis PGA is reduced by NADP.  $2\text{H}$  into phosphoglyceraldehyde
16. (a) Calvin cycle occurs in the stroma of chloroplasts where the products of light reaction (assimilatory power  $\text{NADP} \cdot 2\text{H} + \text{ATP}$ ) are used to form  $\text{CO}_2$  to carbohydrate and it has enzymes essential for fixation of  $\text{CO}_2$  and synthesis of sugar.
17. (b) The new name of dark reaction is carbon assimilation, in which  $\text{CO}_2$  gas reacting with  $\text{H}_2\text{O}$  (liquid) synthesizes solid glucose.
18. (a) In  $\text{C}_3$  cycle, in presence of rubisco (RuBP carboxylase)  $\text{CO}_2$  combines with ribulose 1, 5-bisphosphate (acceptor molecule) to form 3-phosphoglyceric acid or 3-PGA which is the first stable product of carbon reduction cycle.
23. (b) As Calvin cycle takes only one carbon (as  $\text{CO}_2$ ) at a time. So it takes six turns of the cycle to produce a net gain of one hexose or glucose.
25. (c) Reductive carboxylation start with a 5 carbon sugar ribulose – 5 phosphate. 6 mol of this sugar react with 6 mol of ATP (produced in light reaction) to form 6 mol of RuBP and 6 mol ADP
- Ribulose - 5 phosphate  $\xrightarrow{\text{Phosphopentokinase}}$  Ribulose 1, 5-biphosphate + 6ADP
29. (c) Ribulose 1, 5-diphosphate (also known as ribulose biphosphate) a phosphorylated 5 carbon sugar (pentose sugar) it is first attached with  $\text{CO}_2$  in photosynthesis.
31. (b) Calvin cycle is divided into three distinct phase but carboxylation occur only one time.
9. (a) Photorespiration is a process of respiration which takes place in the presence of light and in chloroplasts only. In this process, first of all RuBP is oxygenated in presence of  $\text{O}_2$ . Then, 1 molecule of a 2-C phosphoglycolate and 1 mol. of a 3C PGA are formed from it. The PGA molecule is used in the Calvin cycle. Phosphoglycolate is dephosphorylated and glycolate is formed. Glycolate diffuses out of chloroplast and enters the organelle called peroxisome. Here it is oxidized and becomes glyoxylate. Glyoxylate is used in synthesis of glycine.
11. (d) Photorespiration is quite different from respiration as no ATP or NADH are produced, the energy released being lost as heat. Moreover, the process is harmful to plants because as much as half the photosynthetically fixed  $\text{CO}_2$  (in the form of RuBP) may be lost into the atmosphere through this process.
18. (a) One of the basic features of  $\text{C}_4$  plants is that  $\text{CO}_2$  is trapped by a  $\text{CO}_2$  acceptor, phosphoenol pyruvic acid present in the (PEP) chloroplasts of mesophyll cells of these leaves, leading to the formation of a 4-C compound oxaloacetic acid.
19. (b) In Hatch-Slack pathway, first product of  $\text{CO}_2$  fixation is a 4 carbon compound, oxaloacetic acid hence they are called  $\text{C}_4$  plants. This acid is converted to another 4-C acid, the malic acid.
20. (c) Basic feature of  $\text{C}_4$  plants is the occurrence of "Kranz" (German term meaning halo or wreath) type of leaf anatomy. The vascular bundles, in  $\text{C}_4$  leaves are surrounded by a layer of bundle sheath cells that contain large number of chloroplasts. The chloroplast in  $\text{C}_4$  leaves are dimorphic (Two morphologically distinct type).
23. (d) Photorespiration is absent in  $\text{C}_4$  plants due to presence of kranz anatomy.
27. (b) These are succulent plants with water storing cells.
28. (b) In  $\text{C}_4$  plants agranal chloroplast occur in bundle sheath.
29. (a) In  $\text{C}_4$  plants initial  $\text{CO}_2$  fixation occurs in Mesophyll cells. As a result malic acid is formed. This malic acid is transferred in Bundle sheath chloroplast where it is decarboxylated.
30. (c)  $\text{C}_3$  and  $\text{C}_4$  cycle both occurs in panicum milioides hence it stand intermediate between  $\text{C}_3$  and  $\text{C}_4$  plants.
32. (b)  $\text{C}_4$  plants utilise solar energy most efficiently. Because photosynthesis rate is very high in  $\text{C}_4$  plants e.g., Sugarcane, maize etc.
33. (a) In crassulacean acid metabolism (CAM) plants large amount of acid like malic acid etc. are synthesized at night. The stomata remain closed the day time but remain open at night. CAM plants are succulent drought evading plants.

### **$\text{C}_4$ /CAM/Photorespiration**

1. (d) This pathway was first reported in members of family gramineae (grasses) like sugarcane, maize etc. More than 300 species belong to dicots and the rest belong to monocots. There are no known  $\text{C}_4$  gymnosperms, bryophytes or algae.

38. (b) In CAM plants there is no Kranz anatomy, but there occurs dark acidification, i.e., during night malic acid is formed. This malic acid breaks up into  $\text{CO}_2$  and pyruvic acid in day time and  $\text{CO}_2$  released is utilized in C-3 cycle.
40. (b) In 1965 Kortschak, Hart and Burr working with  $\text{C}^{14}\text{O}_2$  on sugarcane leaves found  $\text{C}_4$  dicarboxylic acid, malate and aspartate to be the major labelled products in very short periods of photosynthesis. This observation was confirmed by M.D. Hatch and C.R. Slack in 1967. The Hatch-Slack pathway, as this alternative  $\text{CO}_2$  fixation is called, has been found to occur in tropical and sub-tropical grasses and some dicotyledons.
46. (a) In  $\text{C}_4$  plants poor supply of  $\text{CO}_2$ . Because there is an internal supply of  $\text{CO}_2$ . So these plants can survive in poor  $\text{CO}_2$  conditions.
47. (c) Phosphoenolpyruvic acid carboxylase fixed  $\text{CO}_2$  in sugarcane. Due to this enzyme  $\text{PEP} + \text{CO}_2$  converted into oxaloacetic acid.
48. (d) Photorespiration is absent in  $\text{C}_4$  plants.
50. (a) PCO or photorespiration is also called  $\text{C}_2$  cycle as there is synthesis of 2-carbon compound.
51. (c) Three conditions are required for photorespiration (1) High  $\text{O}_2$  concentration (2) Low concentration of  $\text{CO}_2$  (3) High light intensity. During photorespiration oxygenation takes place firstly.
52. (d) Glyoxylate is used to form glycine, glycine enters in mitochondria where two glycine molecules give rise to one molecule of serine and one  $\text{CO}_2$ .
53. (b) Two times carboxylation occur in  $\text{C}_4$  cycle, first carboxylation is done by phosphoenolpyruvate and second in bundle sheath cell by Ribulose 1, 5 biphosphate.
54. (b) Bundle sheath chloroplast larger in size, lack grana (Agranal chloroplast) and contain starch grains. Mesophyll chloroplast small in size, contain grana and lack starch grains.
57. (b) The process of photorespiration involves the involvement of chloroplast, peroxysome and mitochondria.

### Bacterial photosynthesis

2. (b) Chemosynthetic bacteria are able to manufacture all their organic food from inorganic raw material in the absence of light.
- $$6\text{CO}_2 + 24[\text{H}] \xrightarrow{\text{Enzymes/Energy}} \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{H}_2\text{O}$$
3. (b) Like cyanobacteria, algae, autotrophic plants and photoautotrophic bacteria also use light energy for reducing  $\text{CO}_2$  to organic compounds but water is never used as a source of electrons in bacteria. Hence, oxygen is never evolved during bacterial photosynthesis.
4. (a) The bacterial pigments are however not contained in chloroplast but are present in structures called chromatophores.
5. (a)  $\text{CO}_2 + 2\text{H}_2\text{S} \xrightarrow{\text{Sunlight}} (\text{CH}_2\text{O}) + 2\text{S} + \text{H}_2\text{O} + \text{Energy}$
6. (d) Photosynthetic bacteria absorb (850-950nm) infra-red wavelength.
7. (c) *Leptothrix*, is a iron bacteria oxidise  $\text{Fe}^{2+} \xrightarrow{\text{(Ferrous)}} \text{Fe}^{3+} \text{(Ferric)}$  + chemical energy.
8. (c) Green bacteria contain green pigment bacteriochlorophyll (chlorobium chlorophyll), which absorbs red light, showing maximum absorption in the region of 650-660.
10. (d) The photosynthetic bacteria use inorganic electron donor such as  $\text{H}_2\text{S}$ ,  $\text{H}_2$ , sulphur compound etc. They contain bacterio-chlorophyll but chlorophyll a is absent.
11. (c) Purple non-sulphur bacteria contain purple pigment bacteriochlorophyll and carry on photosynthesis in presence of simple organic compounds like organic acids and alcohol e.g., *Rhodospirillum rubrum*.
- $$2\text{CH}_3\text{CHOHCH}_3 + \text{CO}_2 \xrightarrow{\text{Sunlight}} (\text{CH}_2\text{O}) + 2\text{CH}_3\text{COCH}_3 + \text{H}_2\text{O}$$
13. (c) The oldest micro-fossils discovered so far are that of photosynthetic cyanobacteria that appeared 3.3 to 3.5 billion years ago.

### Factors affecting photosynthesis

1. (c) During light reaction of photosynthesis  $\text{O}_2$  release as a result of photolysis of water. DCMU is a photosynthetic inhibitor which inactivates the PS-II and inhibit the Hill reaction.
3. (d) Law of limiting factor was proposed by Blackman in 1905. He stated that when a process is conditioned as to its rapidity by a number of separate factors, the rate of the process is limited by the pace of slowest factor.
4. (b) The maximum temperature at which photosynthesis can occur is  $55^\circ\text{C}$  in some desert plants and  $75^\circ\text{C}$  for hot spring algae.
5. (a) German scientist Warburg (1920) reported in *Chlorella* alga that high  $\text{O}_2$  level inhibit rate of photosynthesis and this inhibition of photosynthesis by increased  $\text{O}_2$  concentration is called Warburg's effect.
6. (b) Rate will be increased due to the ejection of  $\text{CO}_2$  from  $\text{NaHCO}_3$ .
7. (d) Blue and red regions of the light spectrum are the most effective in photosynthesis. Blue wavelengths of light carry more energy while red wavelengths have lesser energy. Therefore, the most efficient wavelengths of light effective in photosynthesis are those of light.
8. (b) Compensation point is existed in morning and evening time. At this time the rate of photosynthesis (intake of  $\text{CO}_2$ ) and rate of respiration (outcome of  $\text{CO}_2$ ) is equal. At this point no exchange of  $\text{CO}_2$  is possible through stomata. The unit is lumen.

11. (b) Because blue colour comes first in spectrum light.
12. (c) R. Emerson and C.M. Lewis (1943) observed that the quantum yield of photosynthesis decreased towards the far red end of the spectrum (680nm or longer).
14. (c) Normal conc. of  $\text{CO}_2$  in atmosphere is 0.03% (i.e., 300 ppm). By increases but after that it decreases.
15. (a) Because light reaction is much faster than dark reaction, so in continuous light there is accumulation of ATP and  $\text{NADPH}_2$  and hence reduction in rate of photosynthesis but in discontinuous light, ATP and  $\text{NADPH}_2$  formed in light are fully consumed during dark in reduction of  $\text{CO}_2$  to carbohydrates.
22. (c) If the amount of oxygen in the atmosphere decreases then photosynthesis will increase in  $\text{C}_3$  cycle (wheat) and no change in  $\text{C}_4$  cycle.

### Critical Thinking Questions

4. (b) Normally plants utilize sunlight but marine algae also use moon light, photosynthesis even occur in electric light.
6. (c) RuBP-oxygenase is a form of Rubisco, which constitutes 16% of chloroplast protein. It is the most abundant protein on this planet.
7. (a) Cytochromes – Hence proteins (iron containing proteins) serving as electron carriers in respiration photosynthesis and other oxidative reduction reactions.
8. (b) Reduction of carbon, anabolised organic compound will give ATP during respiration. Photosynthesis is an anabolic and endothermic reaction. It is a mechanism of synthesis of food.
9. (b) Lichen's can photosynthesize at very low temperature. i.e.,  $-24^\circ\text{C}$ .
12. (a) Chlorophyll a occurs in all except photoautotrophic bacteria, i.e., all oxygenic photoautotrophs.
13. (c) Chlorophyll a is bluish-green with empirical formula of  $\text{C}_{55}\text{H}_{72}\text{O}_6\text{N}_4\text{Mg}$ .
16. (b) Purple sulphur bacteria and non-sulphur bacteria contain bacterio-chlorophyll, which is having 2H-atoms more than chl. a and it absorbs 850-950 nm (infra-red) wavelength of light.
18. (d)  $\text{C}_4$  plants mostly in monocot plants (Artiplex, sugarcane, maize, cyperus) and some dicots (Amaranthus).
21. (c) In carboxylation Ribulose – 1, 5 – biphosphate (RuBP) (= Ribulose diphosphate) acts as  $\text{CO}_2$  acceptor and 6 mols of RuBP react with 6 mols of  $\text{CO}_2$  and 6 mols of water giving rise to 12 mols of 3-phosphoglyceric acid.
23. (d) 3 molecules of  $\text{CO}_2$  combine with 3 molecules of RuBP to produce 3 molecules of an unstable 6-C compound which immediately breaks down into molecules of 3-phosphoglyceric acid
28. (d) Chromatophores contain pigments and they are found in blue green algae for photosynthesis.

### Assertion and Reason

1. (b)  $\text{C}_4$  pathway found in tropical angiosperms and called as Hatch and Slack cycle. Here  $\text{CO}_2$  is fixed by 3C compound (phosphoenol pyruvate, PEP).
2. (b) Six molecules of  $\text{CO}_2$  enter Calvin cycle to produce one hexose molecule whereas 18 ATP, 12  $\text{NADPH} + \text{H}^+$  molecules are used up. The light reaction of photosynthesis results in ATP and  $\text{NADPH}_2$  formation.
3. (c) Anthocyanin pigment, present in cell sap of vacuole. It is responsible for the colouration of flower parts. It is not a photosynthetic pigment.
4. (b) Although the efficiency of photosynthesis is uniform over most of the spectrum, it declines significantly in the red, i.e., at wavelength of 680 nm and above. This phenomenon is called red drop. However, it was shown by Emerson that if light at 680 nm is supplemented with light of a shorter wavelength ( $< 600 \text{ nm}$ ), the quantum efficiency of photosynthesis in the red can be restored to normal
5. (a) Small quantity of oxygen is essential for photosynthesis except in some anaerobic bacteria. The inhibition of photosynthesis at high  $\text{O}_2$  levels may be due to (i) Oxygen takes part in oxidation of photosynthetic pigments, intermediates and enzymes in the presence of strong light (photo-oxidation), (ii) Oxygen is a strong quencher of excited state of chlorophyll, (iii) It converts RuBP carboxylase to RuBP-oxygen. At a very high oxygen content the rate of photosynthesis begins to decline in all plants. The phenomenon is called Warburg effect (reduction due to photorespiration).
6. (a)  $\text{C}_4$  photosynthetic pathway is more efficient than  $\text{C}_3$  pathway as  $\text{C}_4$  plants can pick up  $\text{CO}_2$  even when it is found in low concentration. PEP enzymes shows high affinity for  $\text{CO}_2$ .  $\text{C}_4$  plants contain two types of chloroplast (Kranz anatomy) : bundle sheath chloroplast and mesophyll chloroplast. Bundle sheath cells contain calvin cycle enzymes. Due to high concentration of  $\text{CO}_2$  in bundle sheath cells, RuBP carboxylase works only for calvin cycle and not for photorespiration.

Photorespiration is a wasteful process as it works to undo the act of photosynthesis in  $\text{C}_4$  plants. No energy rich compound is produced in this process. When temperature increase more and more photosynthetically fixed carbon is lost by photorespiration thus reducing the efficiency of  $\text{C}_4$  plants.

7. (c) CAM plants do not exhibit the structural compartmentation ( $C_3$  and  $C_4$  cycles taking place in different cells) of conventional  $C_4$  plants. CAM plants fix  $CO_2$  at night because their stomata are open at night and closed during the day.
8. (b) Plants that utilize primarily RuBP to fix  $CO_2$ , which results in the formation of the three-carbon compound 3-PGA, are called  $C_3$  plants. Hatch and Slack proposed a new pathway of  $CO_2$  fixation via the carboxylation of PEP. Because the products are four-carbon compounds, plants exhibiting this pathway are referred to as  $C_4$  plants.
9. (b) Cyclic pathway of photosynthesis is appeared first in some eubacterial species. It is supposed to be the first evidence of production of ATP in the presence of light. During non-cyclic photophosphorylation photolysis of water takes place. Under the influence of light energy and the catalytic action of chlorophyll, water a substance of low energy value, is split up into oxygen and hydrogen. Oxygen is used in the chloroplast. Non-cyclic photophosphorylation is the only natural process which adds molecular oxygen to the atmosphere.
10. (d) The grana stacks of membranes are enriched in PS II and LHC (Light harvesting centre), while there is little ATP synthetase. On the other hand, a fraction of stroma thylakoids is rich in PS I and ATPase and poor in PS II and LHC.
11. (b) In case of cyclic photophosphorylation, the electron, while passing between ferredoxin and plastoquinone and/or over the cytochrome complex the electron loses sufficient energy to form ATP from ADP and inorganic phosphate.
12. (b) The synthesis of ATP via electron flow through the ETS, with oxygen as the terminal electron acceptor, is known as oxidative phosphorylation and takes place in mitochondria. In contrast to the oxidative phosphorylation of mitochondria,  $O_2$  is not used in photophosphorylation of chloroplasts and  $NADP^+$  is last electron acceptor.
13. (c) Each molecule of ribulose-1, 5-biphosphate fixes one molecule of carbon dioxide with the addition of water, thereby resulting in the formation of two molecules of 3-phosphoglyceric acid (3-PGA). The fixation and reduction of one molecule of  $CO_2$  requires three molecules of ATP and two of NADPH, coming from the photochemical reactions.
14. (e) Malic acid or aspartic acid is translocated to bundle sheath cells through plasmodesmata. Inside the bundle sheath cells they are decarboxylated (and deaminated in case of aspartic acid) to form pyruvate and  $CO_2$ .  $CO_2$  is again fixed inside the bundle sheath cells through Calvin cycle. RuBP of Calvin cycle is called secondary or final acceptor of  $CO_2$  in  $C_4$  plants.
15. (e) The overall equation of photosynthesis is
$$CO_2 + 2H_2O + n(h\nu) \rightarrow (CH_2O) + H_2O + O_2.$$
The standard free-energy change for the synthesis of hexose from  $CO_2$  and  $H_2O$  is  $\Delta G^\circ = +686 \text{ kcal}$ . As six molecules of  $CO_2$  is involved to form one molecule of hexose, the energy input per  $CO_2$  molecule will be 114 kcal
16. (a) The energy balance of photosynthesis is :
$$6CO_2 + 12H_2O \xrightarrow{\text{light}} C_6H_{12}O_6 + 6CO_2 + 6H_2O$$
which represents a storage of 686,000 calories per mole. This energy is provided by a total of 12 NADPH and 18 ATP molecules, which represent 750,000 calories. The efficiency reached by the PCR cycle is thus as high as 90% ( $686/750 \times 100 = 90\%$ ).
17. (e) Plants are grouped into two groups depending upon their inability or ability to tolerate high light intensity-shade plants (Sciophytes) and sun plants (Heliophytes). Sciophytes grow in poorly illuminated conditions as below the canopy of tall plants in seek of shade. Heliophytes grow in the open.
18. (e) Less than 1% of the total water absorbed is utilized in photosynthesis. The rest is lost in transpiration. Even a slight increase in transpiration reduces the leaf hydration that cuts down photosynthesis by causing stomatal closure and hence decreased  $CO_2$  absorption, loss of leaf turgidity, reduced absorption of solar radiations and decrease enzymatic activity.

## Photosynthesis in Higher Plants

## Self Evaluation Test

1. In  $C_3$  cycle for the fixation of every  $CO_2$  molecule, the reduction and regeneration steps require  
[AMU (Med.) 2009, 10; CPMT 2010; Kerala PMT 2011]  
(a) 3 ATP and  $NADPH_2$  (b) 2 ATP and 2  $NADPH_2$   
(c) 2 ATP and 3  $NADPH_2$  (d) 3 ATP and 3  $NADPH_2$   
(e) 3 ATP and 1  $NADPH_2$
2. "Impure air is purified in the presence of light and green plants" was first said by  
(a) De Saussure (b) Priestley  
(c) Van Helmont (d) Ingenhousz
3. From which of the following photosynthetic autotrophs receive their energy  
[WB JEE 2008]  
(a) Heat (b) Inorganic chemicals  
(c) Organic chemicals (d) Light
4. During cyclic electron transport, which one of the following is produced  
[J & K CET 2010]  
(a) ATP only (b) Erythrose  
(c)  $NADH_2$  (d) None of these
5. For each molecule of glucose formed in plants, the number of molecule of ATP and  $NADPH_2$  required are respectively  
[MH CET 2006]  
(a) 12 and 18 (b) 18 and 12  
(c) 15 and 10 (d) 3 and 22
6. How many molecules of glycine is required to release one  $CO_2$  molecule in photorespiration  
[AFMC 2004]  
(a) One (b) Two  
(c) Three (d) Four
7. The process in which excess energy is lost by light waves is called  
[JIPMER 2002]  
(a) Fluorescence (b) Photophosphorylation  
(c) Photolysis (d) Photooxidation
8. With respect to compensation point, which of the following is true for  $C_3$  and  $C_4$  plants  
[GUJCET 2007]  
(a) Compensation points of  $C_3$  and  $C_4$  plants are equal  
(b) Compensation point of  $C_3$  plant is higher than  $C_4$  plant  
(c) Compensation point of  $C_4$  plant is higher than  $C_3$  plant  
(d) None of the above
9. A pigment which absorbs red and far-red light is  
[CBSE PMT 1997]  
(a) Phytochrome (b) Carotene  
(c) Cytochrome (d) Xanthophyll
10. Which of the following is formed during photorespiration  
[Kerala PMT 2011]  
(a) Sugar (b) Phosphoglycolate  
(c)  $NADPH$  (d) ATP  
(e) Oxaloacetate
11. Which pigment is absent in chloroplast  
Or  
Which one of the following does not play any role in photosynthesis  
[DUMET 2010]  
(a) Xanthophyll (b) Anthocyanin  
(c) Chlorophyll 'a' (d) Carotene
12. Which one of the following statements is correct for chlorophyll a  
[MP PMT 1995]  
(a) Chlorophyll a is found more than chlorophyll b in leaves of most plants  
(b) Chlorophyll a and b are found in equal proportion in leaves of most plants  
(c) Chlorophyll a is found less than chlorophyll b in leaves of most plants  
(d) Chlorophyll b is found ten fold more than chlorophyll a in leaves of most plants
13. The  $C_4$  plants are different from  $C_3$  plants with reference to the  
[AFMC 1997]  
(a) Substance that accept  $CO_2$  in carbon assimilation  
(b) Type of end product of photosynthesis  
(c) Number of ATP that are consumed in preparing sugar  
(d) Types of pigments involved in photosynthesis
14. Synthesis of food in  $C_4$  pathway occurs in chlorophyll of  
[KCET 2007]  
(a) Guard cells (b) Bundle sheath  
(c) Spongy mesophyll (d) Palisade cells
15.  $NH_3$  Release from  
[MP PMT 2007]  
(a) Photorespiration (b) Dark respiration  
(c) CAM (d) All of these
16. Which of the following fixes  $CO_2$  in carbohydrates  
[BVP 2003]  
(a) Rhodospirillum (b) Nitrobacter  
(c) Rhizobium (d) Bacillus
17. Liberation of  $O_2$  when green cells in water are exposed to sunlight in the presence of suitable acceptor is called  
[KCET 2007]  
(a) Arnon's reaction  
(b) Emerson's enhance effect  
(c) Blackmann's reaction  
(d) Hill's reaction
18. Which of the following is capable of performing photosynthesis at high temperature i.e. at  $50^\circ C$   
(a) *Opuntia* (b) Mango  
(c) Potato (d) None of the above



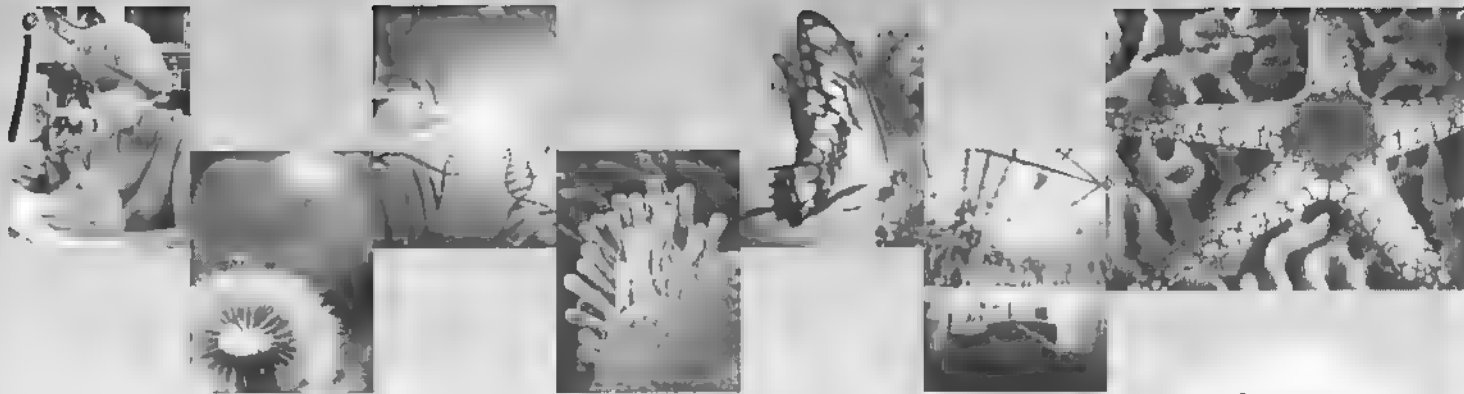
19. The first product of  $\text{CO}_2$  fixation in Hatch and Slack ( $\text{C}_4$ ) cycle in plants is [KCET (Med.) 2001, 10]  
 (a) Formation of oxaloacetate by carboxylation of phosphoenol pyruvate (PEP) in bundle sheath cells  
 (b) Formation of phosphoglyceric acid in mesophyll cells  
 (c) Formation of bundle sheath cells  
 (d) Formation of oxaloacetate by carboxylation of phosphoenol pyruvate (PEP) in the mesophyll cells
20. Optimum temperature for Photosynthesis is [MP PMT 2011]  
 (a)  $10 - 15^\circ\text{C}$  (b)  $20 - 25^\circ\text{C}$   
 (c)  $25 - 30^\circ\text{C}$  (d)  $35 - 40^\circ\text{C}$

## AS Answers and Solutions

1	a	2	b	3	d	4	a	5	b
6	b	7	d	8	b	9	a	10	b
11	b	12	a	13	a	14	b	15	a
16	a	17	d	18	a	19	d	20	c

2. (b) Priestley demonstrated that green plants purify the foul air (i.e., phlogiston) produced by burning of candle and convert it into pure air (i.e., Dephlogiston).
5. (b) During formation of one glucose molecule in plant 3 ATP required for fixation of one  $\text{CO}_2$  molecule. Thus in plants required 18 ATP and 12  $\text{NADPH}_2$ .
6. (b) There is two molecule of glycine used and interact to form one molecule each of serine  $\text{CO}_2$  and  $\text{NH}_3$ .  
 $2\text{Glycine} + \text{H}_2\text{O} + \text{NAD} \rightarrow \text{Serine} + \text{CO}_2 + \text{NH}_3 + \text{NADP}$
7. (d) Certain cell constituents are oxidized by oxygen into  $\text{CO}_2$  as known as photo-oxidation.
8. (b) Under the conditions of sufficient light and low  $\text{CO}_2$  concentration, the rate of photosynthesis equals the rate of respiration (respiration and photorespiration together) in any plant. This concentration of atmospheric  $\text{CO}_2$  absorbed from the atmosphere equals the amount of  $\text{CO}_2$  at which the photosynthesis and respiration become balanced is called -  $\text{CO}_2$  compensation point. This compensation point is achieved when the amount of  $\text{CO}_2$  absorbed from the atmosphere equals the amount of  $\text{CO}_2$  released through plant respiration. However is necessary that available light does not become a limiting factor. At this point, effective photosynthesis becomes nil. The compensation point is higher in  $\text{C}_3$  plants in relation to that in  $\text{C}_4$  plants as rate of photorespiration is high in  $\text{C}_3$  plants.
9. (a) Phytochrome is a proteinaceous pigment found in low concentrations in most plant organs. It exists in two forms  $\text{P}_{\text{sub FR}}$  (or  $\text{P}_{\text{sub 660}}$ ) has an absorption peak at 660nm (red light) and the other  $\text{P}_{\text{sub FR}}$  (or  $\text{P}_{\text{sub 730}}$ ) at 730nm (far-red).
11. (b) Anthocyanin pigment is absent in chloroplast. It is present in cell sap of vacuole and not take any part in photosynthesis.
12. (a) Chlorophyll *a* is found in all autotrophic plants except the photosynthetic bacteria.
13. (a) Here in  $\text{C}_4$  plants,  $\text{CO}_2$  acceptor molecule is PEP (Phosphoenol pyruvate) and in  $\text{C}_3$  plant  $\text{CO}_2$  molecule is RuBP (ribulose 1-5 biphosphate).
16. (a) Rhodospirillum bacteria completed their photosynthesis by bacteriochlorophyll *b*. These are found in mud and stagnant water.
18. (a) For desert plants like *Opuntia* required  $50^\circ\text{C}$  temperature for photosynthesis.
19. (d)  $\text{CO}_2$  taken from the atmosphere is accepted by phosphoenolpyruvic acid (PEP) present in the chloroplast of mesophyll cells of these leaves, leading to the formation of a 4-C compound, oxaloacetic acid (OAA).

\* \* \*



## Chapter

# 4.4

## Respiration in Plants

Cellular respiration is an enzyme controlled process of biological oxidation of food materials in a living cell, using molecular  $O_2$ , producing  $CO_2$  and  $H_2O$ , and releasing energy in small steps and storing it in biologically useful forms, generally ATP.

So respiration is catabolic, exothermic and oxidative process.



**Use of energy :** Cellular activities like active transport, muscle-contraction, bioluminescence, homothermy, locomotion, nerve impulse conduction, cell division, growth, development, seed germination require energy. Main source of energy for these endergonic activities in all living organisms including plants, comes from the oxidation of organic molecules.

The energy released by oxidation of organic molecules is actually transferred to the high energy terminal bonds of ATP, a form that can be readily utilized by the cell to do work. Once ATP is formed, its energy may be utilized at various places in the cell to drive energy- requiring reactions. In these processes, one of the three phosphate groups is removed from the ATP molecule. Thus the role of ATP as an intermediate energy transforming compound between energy releasing and energy consuming reactions.

**Significance of respiration :** Respiration plays a significant role in the life of plants. The important ones are given below :

(1) It releases energy, which is consumed in various metabolic processes necessary for life of plant.

(2) Energy produced can be regulated according to requirement of all activities.

(3) It converts insoluble food into soluble form.

(4) Intermediate products of cell respiration can be used in different metabolic pathways e.g.,

Acetyl- CoA (in the formation of fatty acid, cutin and isoprenoids) ;  $\alpha$  - ketoglutaric acid (in the formation of glutamic acid) ; Oxaloacetic acid (in the formation of aspartic acid, pyrimidines and alkaloids); Succinyl- CoA (synthesis of pyrrole compounds of chlorophyll).

(5) It liberates carbon dioxide, which is used in photosynthesis.

(6) Krebs cycle is a common pathway of oxidative breakdown of carbohydrates, fatty acids and amino acids.

(7) It activates the different meristematic tissues of the plant.

$CO_2$  intake in photosynthesis balanced with  $CO_2$  release in respiration = Compensation point.

### Comparison between respiration and combustion :

According to Lavoisier cell respiration resembles the combustion (e.g., burning of coal, wood, oil etc.) in the breakdown of complex organic compounds in the presence of oxygen and production of carbon dioxide and energy, but there are certain fundamental differences between the two processes :

Table : 4.4-1

## Differences between cell respiration and combustion

S.No.	Character	Cell respiration	Combustion
(i)	Nature of process	Biochemical and stepped process.	Physico-chemical and spontaneous process
(ii)	Site of occurrence	Inside the cells.	Non-cellular.
(iii)	Control	Biological control.	Uncontrolled
(iv)	Energy release	Energy released in steps.	Large amount of energy is released at a time
(v)	Temperature	Remain within limits.	Rises very high.
(vi)	Light	No light is produced	Light may be produced.
(vii)	Enzymes	Controlled by enzymes.	Not controlled by enzymes.
(viii)	Intermediates	A number of intermediates are produced	No intermediate is produced.

## Phases of respiration

There are three phases of respiration :

(1) **External respiration** : It is the exchange of respiratory gases ( $O_2$  and  $CO_2$ ) between an organism and its environment.

(2) **Internal or Tissue respiration** : Exchange of respiratory gases between tissue and extra cellular environment .

Both the exchange of gases occur on the principle of diffusion.

(3) **Cellular respiration** : It is an enzymatically-controlled stepped **chemical process** in which glucose is oxidised inside the mitochondria to produce energy-rich ATP molecules with high-energy bonds.

So, respiration is a biochemical process.

## Respiratory substrate or Fuel

In respiration many types of high energy compounds are oxidised. These are called respiratory substrate or respiratory fuel and may include carbohydrates, fats and protein.

(1) **Carbohydrate** : Carbohydrates such as glucose, fructose (hexoses), sucrose (disaccharide) or starch, insulin, hemicellulose (polysaccharide) etc; are the main substrates. Glucose are the first energy rich compounds to be oxidised during respiration. Brain cells of mammals utilized only glucose as respiratory substrate. Complex carbohydrates are hydrolysed into hexose sugars before being utilized as respiratory substrates. The energy present in one gram carbohydrate is 4.4 Kcal or 18.4 kJ.

(2) **Fats** : Under certain conditions (mainly when carbohydrate reserves have been exhausted) fats are also oxidised. Fat are used as respiratory substrate after their hydrolysis to fatty acids and glycerol by lipase and their subsequent conversion to hexose sugars. The energy present in one gram of fats is 9.8 Kcal or 41kJ, which is maximum as compared to another substrate

The respiration using carbohydrate and fat as respiratory substrate, called floating respiration (Blackmann).

(3) **Protein** : In the absence of carbohydrate and fats , protein also serves as respiratory substrate. The energy present in one gram of protein is : 4.8 Kcal or 20 kJ. when protein are used as respiratory substrate respiration is called protoplasmic respiration.

## Types of respiratory organism

Organism can be grouped into following four classes on the basis of their respiratory habit.

(1) **Obligate aerobes** : These organisms can respire only in the presence of oxygen. Thus oxygen is essential for their survival.

(2) **Facultative anaerobes** : Such organisms usually respire aerobically (i.e., in the presence of oxygen) but under certain condition may also respire anaerobically (e.g., Yeast, parasites of the alimentary canal)

(3) **Obligate anaerobes** : These organisms normally respire anaerobically which is their major ATP- yielding process. Such organisms are in fact killed in the presence of substantial amount of oxygen (e.g., *Clostridium botulinum* and *C. tetani*).

(4) **Facultative aerobes** : These are primarily anaerobic organisms but under certain condition may also respire aerobically

## Types of respiration

On the basis of the availability of oxygen and the complete or incomplete oxidation of respiratory substrate. The respiration may be either of the following two types : Aerobic respiration and Anaerobic respiration

## Aerobic respiration

It uses oxygen and completely oxidises the organic food mainly carbohydrate (Sugars) to carbon dioxide and water. It therefore, releases the entire energy available in glucose.



It is divided into two phases : Glycolysis, Aerobic oxidation of pyruvic acid.

## Glycolysis / EMP pathway

(1) **Discovery** : It was given by Embden, Meyerhof and Parnas in 1930. It is the first stage of breakdown of glucose in the cell.

(2) **Definition** : Glycolysis ( Gr. *glykys*= sweet, sugar; *lysis*= breaking) is a stepped process by which one molecule of glucose (6c) breaks into two molecules of pyruvic acid (3c).

(3) **Site of occurrence** : Glycolysis takes place in the cytoplasm and does not use oxygen. Thus, it is an anaerobic pathway. In fact, it occurs in both aerobic and anaerobic respiration.

(4) **Inter conversions of sugars** : Different forms of carbohydrate before entering in glycolysis get converted into simplest form like glucose, glucose 6-phosphate or fructose 6-phosphate. Phosphorylation of glucose is the first step of glycolysis. Then these sugars are metabolized into the glycolysis.

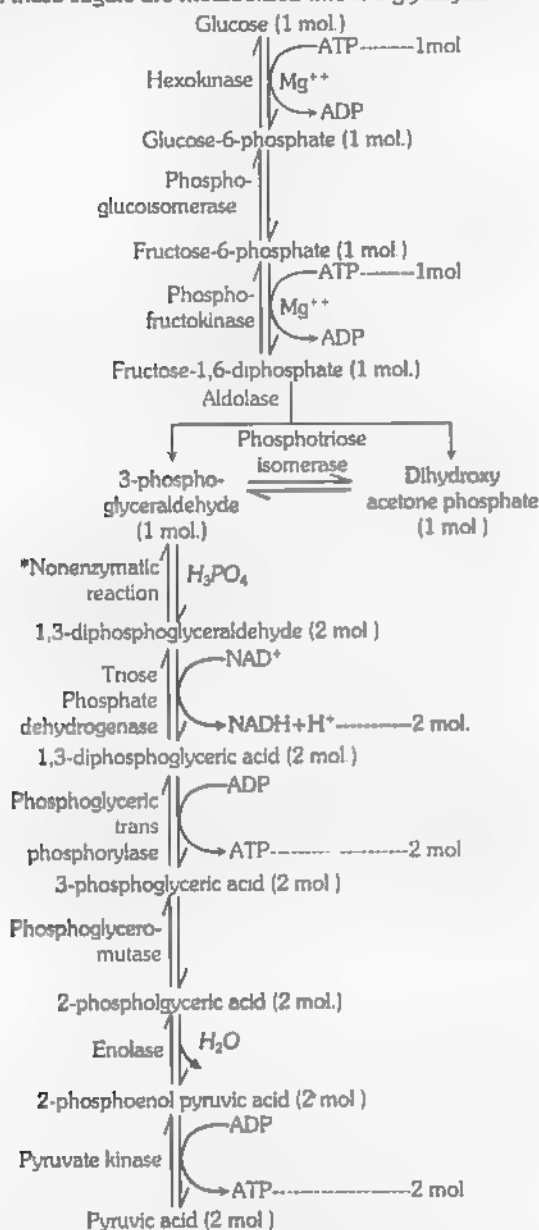


Fig : 4.4-1 Glycolysis or EMP-Pathway

(5) **Special features of glycolysis** : The special features of glycolysis can be summarised as follows :

- Each molecule of glucose produces 2 molecules of pyruvic acid at the end of the glycolysis.
- The net gain of ATP in this process is two ATP molecules (four ATPs are formed in glycolysis but two of them are used up in the reaction)
- During the conversion of 1, 3-diphosphoglyceraldehyde into 1, 3-diphosphoglyceric acid one molecule of NADH<sub>2</sub> is formed. As each molecule of glucose yields two molecules of 1,3-diphosphoglyceric acid, hence each molecule of glucose forms 2 molecules of NADH<sub>2</sub>.

(iv) During aerobic respiration (when oxygen is available) each NADH<sub>2</sub> forms 3 ATP and H<sub>2</sub>O through electron transport system of mitochondria. In this process  $\frac{1}{2}$  O<sub>2</sub> molecule is utilized for the synthesis of each water molecule.

In this way during aerobic respiration there is additional gain of 6 ATP in glycolysis



(v) Reaction of glycolysis do not require oxygen and there is no output of CO<sub>2</sub>.

(vi) Formation of 1, 3- diphosphoglyceraldehyde called non enzymatic phosphorylation.

(vii) Overall reaction of glycolysis represented by following reaction :



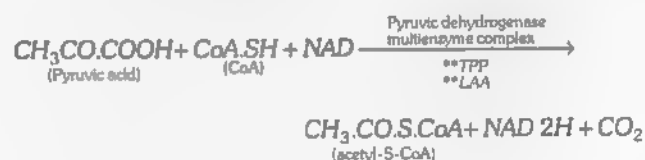
Table : 4.4-2 Total input and output materials in glycolysis

Total Input	Total Output
1 molecule of glucose (6 C)	2 molecules of pyruvate (2×3 C)
2 ATP	4 ATP
4 ADP	2 ADP
2 × NAD <sup>+</sup>	2× NADH + 2H <sup>+</sup>
2 Pi	2 × H <sub>2</sub> O

#### Aerobic oxidation of pyruvic acid

(1) **Oxidative decarboxylation of pyruvic acid** : If sufficient O<sub>2</sub> is available, each 3-carbon pyruvate molecule (CH<sub>3</sub>COCOOH) enters the mitochondrial matrix where its oxidation is completed by aerobic means. It is called gateway step or link reaction between glycolysis and Kreb's cycle.

Decarboxylation and dehydration :



\*\*TPP=Thiamine pyrophosphate

\*\*LAA=Lipoic acid amide

Acetyl CoA is a common intermediate of carbohydrate and fat metabolism. Latter this acetyl CoA from both the sources enters Kreb's cycle. The formation of acetyl CoA is involved with some cofactors like Mg<sup>++</sup>, thiamine pyrophosphate Vit B<sub>1</sub>, NAD<sup>+</sup>, CoA and lipoic acid. This reaction is not a part of Kreb's cycle.

#### (2) Kreb's cycle / TCA cycle / Citric acid cycle

**Discovery** : This cycle has been named after the German biochemist Sir Hans Krebs who discovered it in 1937. He won Noble Prize for this work in 1953. Krebs cycle is also called the citric acid cycle after one of the participating compounds. It takes place in the mitochondrial matrix.

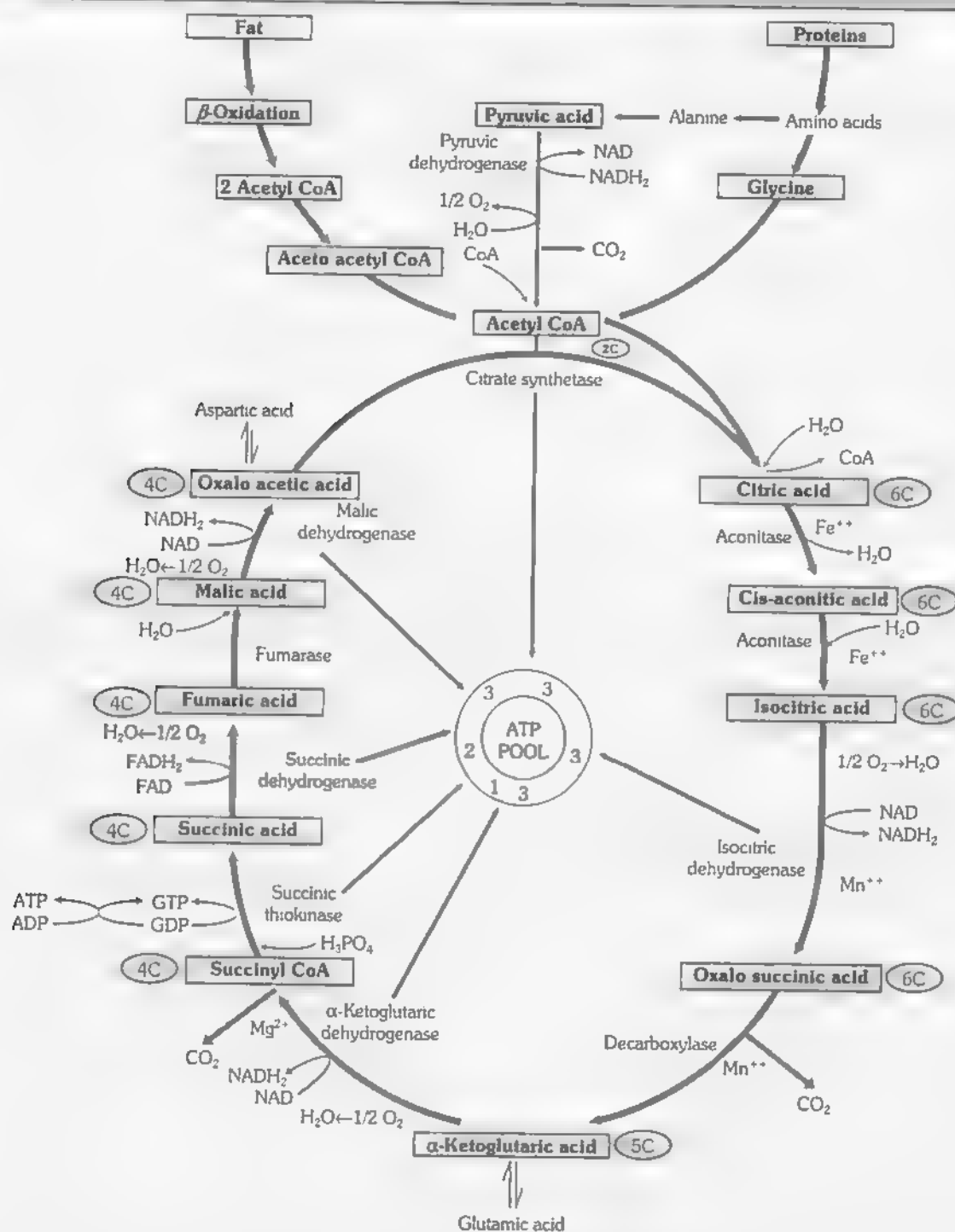


Fig : 4.4-2 Diagrammatic representation of oxidative decarboxylation of pyruvic acid and different chemical reactions in Krebs's cycle starting from Acetyl CoA

#### Summary of Krebs's cycle

(i) All the enzymes, reactants, intermediates and products of TCA cycle also are found in aqueous solution in the matrix, except the succinate dehydrogenase (mitochondrial marker enzyme) which is located in the inner mitochondrial membrane.

(ii) Oxidation of one mole of acetyl CoA uses 4 molecules of water and releases one molecule of water.

(iii) Liberates 2 molecules of carbon dioxide.

(iv) Gives off 4 pairs of hydrogen atoms.

(v) Produces one GTP/ATP molecule during the formation of succinate.

(vi) One mole of acetyl CoA gives 12 ATP during oxidation in Krebs cycle.

(vii) Regenerates oxaloacetate used in last cycle for reuse.

The above summary is for one molecule of acetyl coenzyme A. There are two acetyl coenzyme A molecules formed from one molecule of glucose by glycolysis and oxidative decarboxylation of pyruvate.

Table : 4.4-3 Difference between Glycolysis and Krebs's cycle

Glycolysis	Kreb's cycle
It takes place in the cytoplasm.	It takes place in the matrix of mitochondria.
It occurs in aerobic as well as anaerobic respiration	It occurs in aerobic respiration only
It consists of 9 steps.	It consists of 8 steps.
It is a linear pathway.	It is a cyclic pathway.
It oxidizes glucose partly, producing pyruvate.	It oxidises acetyl coenzyme A fully
It consumes 2 ATP molecules.	It does not consume ATP
It generates 2 ATP molecules net from 1 glucose molecules	It generates 2 GTP ATP molecules from 2 succinyl coenzyme A molecules
It yields 2 NADH per glucose molecule	It yields 6 NADH molecules and 2 FADH <sub>2</sub> molecules from 2 acetyl coenzyme A molecules
It does not produce CO <sub>2</sub> .	It produces CO <sub>2</sub> .
All enzyme catalysing glycolytic reactions are dissolved in cytosol.	Two enzymes of Krebs cycle reactions are located in the inner mitochondrial membrane, all others are dissolved in matrix.

Product formed during aerobic respiration by Glycolysis and Krebs's cycle.

Table : 4.4-4 Total formation of ATP

ATP formation in Glycolysis			
	Steps	Product of reactions	In terms of ATP
ATP formation by substrate phosphorylation	1, 3-diphosphoglyceric acid (2 moles) →	2 ATP	2 ATP
	3 phosphoglyceric acid (2 moles)	2 ATP	2 ATP
	Phosphoenolpyruvic acid (2 moles) → Pyruvic acid (2 moles)		
		Total	4 ATP
ATP formation by oxidative phosphorylation or ETC	1, 3 - diphosphoglyceraldehyde (2 moles)	2 NADH <sub>2</sub>	6 ATP
	1, 3 - diphosphoglyceric acid (2 moles)		
	Total ATP formed	4 + 6 ATP =	10 ATP
ATP consumed in Glycolysis	Glucose (1 mole) → Glucose 6 phosphate (1 mole)	- 1 ATP	- 1 ATP
	Fructose 6 phosphate (1 mole) → Fructose 1, 6-diphosphate (1 mole)	- 1 ATP	- 1 ATP
		Total	2 ATP
	Net gain of ATP = total ATP formed - Total ATP consumed	10 ATP - 2ATP	8 ATP
ATP formation in Kreb's cycle			
ATP formation by substrate phosphorylation	Succinyl CoA (2 mols) →	2 GTP	2 ATP
	Succinic acid (2 mols)		
		Total	2 ATP
ATP formation by oxidative phosphorylation or ETC	Pyruvic acid (2 mols) →	2 NADH <sub>2</sub>	6 ATP *
	Acetyl CoA (2 mols)		
	Isocitric acid (2 mols) →	2 NADH <sub>2</sub>	6 ATP
	Oxalosuccinic acid (2 mols)		
	α-Ketoglutaric acid (2 mols) →	2 NADH <sub>2</sub>	6 ATP
	Succinyl CoA (2 mols)		
	Succinic acid (2 mols) →	2 FADH <sub>2</sub>	4 ATP
	Fumaric acid (2 mols)		
	Malic acid (2 mols) →	2 NADH <sub>2</sub>	6 ATP
	Oxaloacetic acid (2 mols)		
		Total	28 ATP
	Net gain in Kreb's cycle (substrate phosphorylation + oxidative phosphorylation)	2ATP + 28 ATP	30 ATP

Net gain of ATP in glycolysis and Kreb's cycle	Net gain of ATP in glycolysis + Net gain of ATP in Kreb's cycle	8 ATP + 30 ATP	38 ATP
Over all ATP production by oxidative phosphorylation or ETC	ATP formed by oxidative phosphorylation in glycolysis + ATP formed by oxidative phosphorylation or ETC.	6 ATP + 28 ATP	34 ATP

22 ATP produced by oxidation of  $\text{NADH}_2$  and  $\text{FADH}_2$  in Kreb's cycle and 6 ATP comes from oxidative decarboxylation of pyruvic acid.

\* These ATPs are not included neither in glycolysis nor kreb's cycle.

**Table : 4.4-5 Formation and use of water**

<b>Formation of water molecules</b>		
Formation of water molecules in glycolysis	2 phosphoglyceric acid (2 mols) $\xrightarrow{-\text{H}_2\text{O}}$ 2 phosphoenol pyruvic acid (2 mols)	$2\text{H}_2\text{O}$
	1, 3-diphosphoglyceric acid $\xrightarrow{-\text{H}_2\text{O}}$ 1, 3 diphosphoglyceric acid	$2\text{H}_2\text{O}$
	Total water molecules formed in glycolysis	$4\text{H}_2\text{O}$
Formation of water molecules in kreb's cycle	One molecule of water in each of the five oxidation reactions (these reactions occur twice as there are two molecules of pyruvic acid)	$10\text{H}_2\text{O}$
	Other than oxidation reaction Citric acid (2 mols) $\rightarrow$ Cis-aconitic acid (2 mols)	$2\text{H}_2\text{O}$
	Total water molecules formed in Kreb's cycle	$12\text{H}_2\text{O}$
	<b>Total water molecules formed in aerobic respiration (Glycolysis + Kreb's cycle including activation of pyruvates)</b>	<b><math>16\text{H}_2\text{O}</math></b>
<b>Use of water molecules</b>		
Use of water in Glycolysis	3-phosphoglyceric acid (2 mols) $\xrightarrow{+\text{H}_2\text{O}}$ 1, 3 diphosphoglyceric acid (2 mols)	$2\text{H}_2\text{O}$
	Total water molecule used in glycolysis	$2\text{H}_2\text{O}$
Use of water in Kreb's cycle	Oxaloacetic acid (2 mols) $\xrightarrow{+\text{H}_2\text{O}}$ Citric acid (2 mols)	$2\text{H}_2\text{O}$
	Cis aconitic acid (2 mols) $\xrightarrow{+\text{H}_2\text{O}}$ Isocitric acid (2 mols)	$2\text{H}_2\text{O}$
	Succinyl CoA (2 mols) $\xrightarrow{+\text{H}_2\text{O}}$ Succinic acid (2 mols)	$2\text{H}_2\text{O}$
	Fumaric acid (2 mols) $\xrightarrow{+\text{H}_2\text{O}}$ Malic acid (2 mols)	$2\text{H}_2\text{O}$
	Total water molecules used in Kreb's cycle	$8\text{H}_2\text{O}$
	Total water molecules used in aerobic respiration (Glycolysis + Kreb's cycle)	$10\text{H}_2\text{O}$
Net gain of water molecules in aerobic respiration	<b>Number of water molecules formed – Number of water molecules used = ( <math>16\text{H}_2\text{O} - 10\text{H}_2\text{O}</math> )</b>	<b><math>6\text{H}_2\text{O}</math></b>

**Table : 4.4-6 Evolution of carbon dioxide**

Pyruvic acid (2 mols) $\xrightarrow{-\text{CO}_2}$ Acetyl CoA (2 mols)	$2\text{CO}_2$
Oxalosuccinic acid $\xrightarrow{-\text{CO}_2}$ $\alpha$ ketoglutaric acid (2 mols)	$2\text{CO}_2$
$\alpha$ Ketoglutaric acid (2 mols) $\xrightarrow{-\text{CO}_2}$ Succinyl CoA (2 mols)	$2\text{CO}_2$
<b>Total <math>\text{CO}_2</math> molecules released in aerobic respiration</b>	<b><math>6\text{CO}_2</math></b>

**Table : 4.4-7 Use of  $\text{O}_2$  (Oxygen)**

Use of oxygen in Glycolysis	1, 3-diphosphoglyceric acid (2 mols) $\xrightarrow{+\frac{1}{2}\text{O}_2}$ 1, 3-diphosphoglyceric acid (2 mols)	$1\text{O}_2$
Use of oxygen in Kreb's cycle	Five oxidation reactions of Kreb's cycle (2 times)	$5\text{O}_2$
	<b>Total <math>\text{O}_2</math> molecules required for aerobic respiration</b>	<b><math>6\text{O}_2</math></b>

**Energy storage and energy transfer :** In respiration energy released takes in the form of chemical energy, stored in a form called ATP. Energy transfer of biological oxidation hinges on the formation of labile high energy phosphate bonds of ATP. Nicotinamide adenine dinucleotide phosphate (NAD), Flavin adenine dinucleotide (FAD), Guanosine triphosphate are also the product of respiration and converted to ATP by electron transport system.

#### Adenosine triphosphate

There are several compounds like NAD, FAD, GTP and ATP are known as energy yielding compounds. The best known, and probably the most important of these are adenosine triphosphate (ATP). It serves as the energy currency of the cell.

**Structure of ATP :** Adenosine triphosphate is a nucleotide consisting of three main constituents;

- (i) A nitrogen contain purine base (Adenine).
- (ii) A five carbon sugar ribose.
- (ii) Three inorganic phosphate groups.

An ATP molecule is structurally most similar to a RNA molecule.

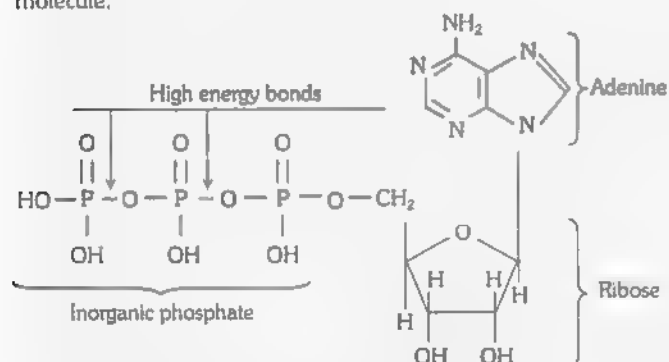
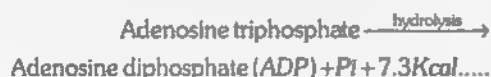


Fig : 4.4-3 Structure of ATP

The bonds attaching the last two phosphate to the rest of the molecule are high energy bonds (~) contain more than twice the energy of an average chemical bond.

**ATP hydrolysis :** The energy is usually released from ATP by hydrolysing the terminal phosphate groups.



**Phosphorylation :** The ATP hydrolysis reactions are reversible because ATP are synthesized from ADP,  $\text{P}_i$  and energy (take up for the bond formation).

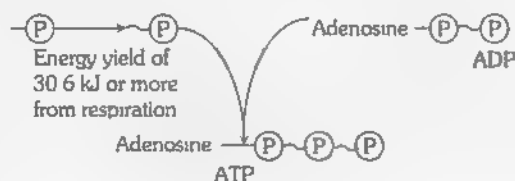


Fig : 4.4-4 Phosphorylation

The addition of phosphate group to ADP and AMP called phosphorylation. Energy required for the bond formation is equal to the energy released in hydrolysis. The significant role of ATP as an intermediate energy transfer compound.

Oxysomes acts as the unit of phosphorylation in respiration by the formation of ATP from ADP. These are present cristae of mitochondria.

**Major functions of ATP :** ATP molecules receive the energy, which released in exergonic reactions and make this energy available for various endergonic reactions. Some of the important process in which ATP is utilized are as follows :

- (i) Synthesis of carbohydrates, proteins, fats, etc.
- (ii) Translocation of organic food.
- (iii) Absorption of organic and inorganic food.
- (iv) Protoplasmic streaming.
- (v) Growth.

**Nicotinamide adenine dinucleotide phosphate/ Nicotinamide adenine dinucleotide (NADP/NAD) :** It is called universal hydrogen acceptor, produced during aerobic respiration (glycolysis+ Kreb's cycle) and also in anaerobic respiration, work as coenzyme in ATP generation Via electron transport system. NADP have one additional phosphate.

NAD plays a crucial role in dehydrogenation processes. Some dehydrogenases do not work with NAD, but react with NADP (Nicotinamide adenine dinucleotide phosphate). Formerly called Coenzyme II or Trphosphopyridine nucleotide = TPN Nicotinamide is a vitamin of B group.

First NAD and NADP both functions as hydrogen acceptors. Later H ions and electrons ( $e^-$ ) from these are transported through a chain of carriers and after being released at the end of a chain react with  $\text{O}_2$  and from  $\text{H}_2\text{O}$  (see Electron Transport chain). During the release of 2 electron from  $2\text{H}^+$  atoms from NAD.  $2\text{H}$  and their reaction with  $\text{O}_2$  to form water, 3 ATP molecules are synthesized.

(3) **Electron transport system :** The electron transmitter system is also called electron transport chain (ETC), or cytochrome system (CS), as five out of these nine carriers are cytochrome. It is the major source of cells energy, in the respiratory breakdown of simple carbohydrates intermediates like phosphoglyceraldehyde, pyruvic acid, isocitric acid,  $\alpha$ -ketoglutaric acid, succinic acid and malic acid are oxidised. The oxidation in all these brought about by the removal of a pair of hydrogen atoms ( $2\text{H}$ ) from each of them. This final stage of respiration is carried out in ETS, located in the inner membrane of mitochondria (In prokaryotes the ETS is located in mesosomes of plasma membrane). The system consists of series of precisely arranged nine electron carriers (coenzyme) in the inner membrane of the mitochondrion, including the folds or cristae of this membrane. These nine electron-carriers function in a specific sequence and are :

Nicotinamide adenine dinucleotide (NAD), Flavin mononucleotide (FMN), Flavin adenine dinucleotide (FAD), Coenzyme-Q or ubiquinone, Cytochrome-b, Cytochrome- $c_1$ , Cytochrome-c, Cytochrome-a and Cytochrome- $a_3$ ,



The first carrier in the chain is a flavoprotein which is reduced by  $\text{NADH}_2$ . Coenzyme passes these electron to the cytochromes arranged in the sequence of  $b-c_1-c-a-a_3$ , finally pass the electron to molecular oxygen. In this transport, the electrons tend to flow from electro-negative to electro-positive system, so there is a decrease in free energy and some energy is released so amount of energy with the electrons goes on decreasing. During electron-transfer, the electron-donor gets oxidised, while electron-acceptor gets reduced so these transfers involve redox-reaction and are catalysed by enzymes, called reductases. Oxidation and reduction are complimentary. This oxidation-reduction reaction over the ETC is called biological oxidation.



here, electron-donor and electron-acceptor form redox pair.

During the electron transfers, the energy released at some steps is so high that ATP is formed by the phosphorylation of ADP in the presence of enzyme ATP synthetase present in the head of  $F_1$ -particles present on the mitochondrial cristae. This process of ATP synthesis during oxidation of coenzyme is called oxidative phosphorylation, so ETS is also called oxidative phosphorylation pathways.



From the cytochrome  $a_3$ , two electrons are received by oxygen atom which also receives two proton ( $\text{H}^+$ ) from the mitochondrial matrix to form water molecule. So the final acceptor electrons is oxygen. So the reaction



in many steps through ETC, so the most of the energy can be derived into a storage and usable form.

(i) **Two route systems of ETC** : The pairs of hydrogen atoms from respiratory intermediates are received either by  $\text{NAD}^+$  or FAD coenzymes which becomes reduced to  $\text{NADH}_2$  and  $\text{FADH}_2$ . These reduced coenzyme pass the electrons on to ETC. Thus, regeneration of  $\text{NAD}^+$  or FAD takes place in ETC. There are two routes ETC :

(a) **Route 1** :  $\text{NADH}_2$  passes their electrons to Co-Q through FAD. In route 1 FAD is the first electron carrier. 3 ATP molecules are produced during the transfer of electron on following steps :

NAD to FAD

Cyt b to Cyt  $c_1$  and

Cyt a to Cyt  $a_3$

(b) **Route 2** :  $\text{FADH}_2$  passes their electron directly to FAD. 2 ATP molecules are produced during the transfer of electron on following steps.

Cyt b to Cyt  $c_1$  and

Cyt a to Cyt  $a_3$

(ii) **Structure of mitochondria in relation to oxidative function** : On inner side of mitochondria elementary particles or  $F_0$ - $F_1$  complex of ATPase complex or elementary particle (oxysomes) are found. Previously it was considered that elementary particles contain all the enzyme of oxidative phosphorylation and electron transport chain.

Component of electron transport chain are located in the inner membrane in the form of respiratory chain complexes. For complexes following theories are given :

(a) **Four complex theory** : According to Devid green electron transport chain contains 4 complexes-

**Complex I** : Comprises NADH dehydrogenase and its 6 Iron Sulphur centers (Fe-S).

**Complex II** : Consists of Succinate dehydrogenase and its 3 Iron Sulphur centers.

**Complex III** : Consists of cytochrome b and c, and a specific Iron-Sulphur centers.

**Complex IV** : Comprises cytochromes a and  $a_3$ .

(b) **Five complex theory** : According to Hatefi, (1976), Complex I to Complex IV are related to the electron transport.

□ Complex V related to mainly with ATP synthesis, so it is called ATPase /ATP synthesis complex.

□ The head piece ( $F_1$ ) of the oxysome consists of 5 hydrophobic subunits ( $\alpha, \beta, \gamma, \delta, \epsilon$ ), which are responsible for ATPase functioning.

□ The stalk ( $F_0$ ) contain  $F_5$  (oligomycin sensitivity conferring protein) i.e., CSCP and  $F_6$ .  $F_0$  are related to the proton channel and embeded fully in thickness of inner mitochondrial membrane.

□ Five complex i.e., I, II, III, IV, V, have been isolated from mitochondrial membrane by chemical treatment.

□ Complex I : NADH/NADPH : CoQ reductase

Complex II : Succinate : CoQ reductase

Complex III : Reduced CoQ ( $\text{CoQH}_2$ ) : cytochrome C reductase

Complex IV : Cytochrome C oxidase

Complex V : ATPase

Cytochrome C and Q are mobile components of the respiratory chain.

(iii) **Oxidative phosphorylation** : The process of ATP synthesis during oxidation of reduced coenzymes in ETC is called oxidative phosphorylation.

Peter Mitchell (1961) proposed the chemiosmotic mechanism of ATP synthesis (Noble prize in 1978) which states that ATP synthesis occurs due to  $\text{H}^+$ -flow through a membrane. It involves two steps :

(a) **Development of proton gradient.** At each step of ETC, the electron-acceptor has a higher electron-affinity than the electron-donor. The energy from electron-transport is used to move the proton ( $H^+$ ) from the mitochondrial matrix to inter-membranous or outer chamber. Three pairs of protons are pushed to outer chamber during the movement of electrons along route I while two pairs of protons are moved to outer chamber during the movement of electrons along route-II. This generates a pH-gradient across the inner mitochondrial membrane with protons ( $H^+$ ) concentration higher in the outer chamber than in the mitochondrial matrix. This difference in  $H^+$  concentration across the inner mitochondrial membrane is called proton-gradient ( $\Delta pH$ ). Due to proton gradient, an electrical potential ( $\Delta\psi$ ) is developed across the inner mitochondrial membrane as the matrix is now electronegative with respect to the intermembranous (outer) chamber. The proton gradient and membrane electric potential collectively called proton motive force.

(b) **Proton flow :** Due to proton-gradient, the protons returns to the matrix while passing through proton channel of  $F_0F_1$  ATPase. This proton gradient activates the enzyme ATP synthetase or  $F_0 - F_1$  ATPase.

ATP synthetase controls the formation of ATP from ADP and inorganic phosphate in the presence of energy.

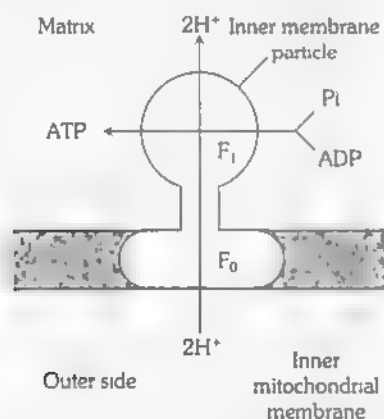


Fig : 4.4-5 ATP synthesis by inner membrane particles of mitochondria

(iv) **Role of shuttle system in energy production :** Glycolysis occurs in the cytoplasm outside the mitochondrion in which  $2NADH_2$  molecules are produced but ETC is located along inner mitochondrial membrane, so  $NADH_2$  of glycolysis must enter inside the mitochondrion to release energy. But the inner mitochondrial membrane is impermeable to  $NADH_2$ . In mitochondrial membrane, there are 2 shuttle-system, each formed of carrier-molecule

These shuttle systems are :

(a) **Malate-Aspartate shuttle :** When this electron shuttle occurs, transfer of electrons from  $NADPH_2$  in cytoplasm occurs to NAD inside the mitochondria. This is more efficient and result in production of 38 ATP molecules.

(b) **Glycerol-Phosphate shuttle :** In this shuttle transfer of electrons from  $NADH_2$  in cytoplasm occurs to FAD inside mitochondria and it results in production of 36 ATP molecules. It is less efficient and results in the reduction of FAD inside the mitochondrion.

Which shuttle predominates depends on the particular species and tissues involved, for example : 38 ATP are formed in kidney, heart and liver cell while 36 ATP molecules are formed in muscle cells and nerve cells. In these cells glycerol-phosphate shuttle is predominant and 2 ATP formed from  $NADH_2$

## Other pathways of glucose oxidation

### (1) Entner-Doudoroff pathway

**Discovery :** Entner-Doudoroff path discovered by Entner & Doudoroff. This pathway is also called glycolysis of bacteria.

Certain bacteria such as *Pseudomonas sacchorophila*, *P. fluorescens*, *P. lindneri* and *P. averginosa* lack phosphofructokinase enzyme. They can not degrade glucose by glycolytic process.

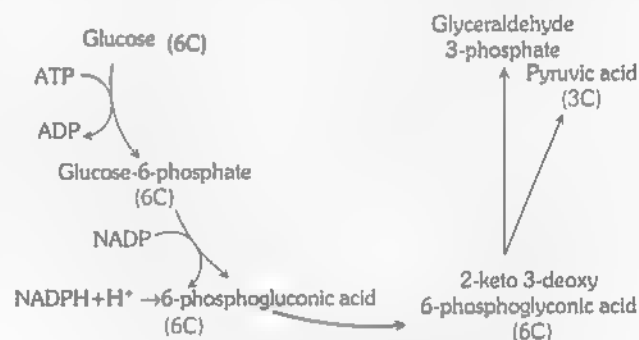


Fig : 4.4-6 Schematic representation of Entner-Doudoroff pathway

### (2) Pentose phosphate pathway

(i) **Discovery :** It is also called as Hexose monophosphate (HMP) shunt or Warburg Dickens pathway or direct oxidation pathway. It provides an alternative pathway for breakdown of glucose which is independent of EMP pathway (glycolysis) and Krebs cycle. Its existence was suggested for the first time by Warburg *et al.* (1935) and Dickens (1938). Most of the reaction of this cycle were described by Horecker *et al.* (1951) and Racker (1954).

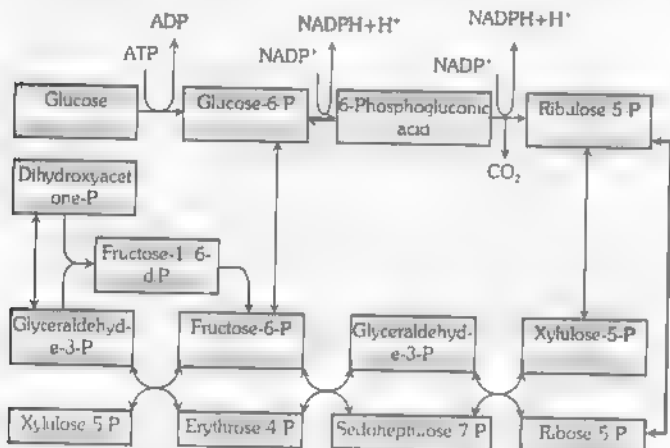
(ii) **Occurrence :** Pentose phosphate pathway that exists in many organisms. This pathway takes place in the cytoplasm and requires oxygen for its entire operation.

(iii) **Description :** There are two types of evidences in support of the existence of such an alternative pathway-works on the inhibiting action of malonic acid on the Krebs cycle and studies with the radioactive ( $C^{14}$ ).

Twelve molecules of  $\text{NADH}_2$  formed in the reaction can be oxidised back to 12  $\text{NADP}$  with the help of the cytochrome system and oxygen of the air.



In this electron transfer process, 36 molecules of ATP are synthesized.



**Fig : 4.4-7 Hexose monophosphate shunt**

#### (iv) Significance of PPP

(a) It is the only pathway of carbohydrate oxidation that gives  $NADPH_2$ , Which is needed for synthetic action like synthesis of fatty acid (in adipose tissues) and amino acids (in liver).

(b) It synthesizes 3C-glyceraldehyde-3-P, 3C-dihydroxy acetone phosphate, 4C-erythrose-4-P, 5C-ribose phosphate, 5C-xylulose phosphate, 5C-ribose phosphate, 6 C-Fructose 6-phosphate, 7C-sedoheptulose-7-phosphate.

(c) It is the major pathway by which necessary ribose and deoxyribose are supplied in the biosynthesis of nucleotides and nucleic acid.

d) Erythrose 4 phosphate for the synthesis of lignin, oxine, anthocyanine and aromatic amino acid (phenylalanine, tyrosine, and tryptophan).

(e) Young growing tissues appears to use to the Krebs cycle as the predominant pathway for glucose oxidation, while aerial parts of the plants and other tissues seem to utilise the PPP as well as the Krebs cycle.

(f) It gives 6  $\text{CO}_2$ , required for photosynthesis.

(g) Ribulose five phosphate is used in photosynthesis to produce RuBP which act as primary  $\text{CO}_2$  acceptor in  $\text{C}_3$  cycle.

(3) **Cyanide resistant pathway** : Cyanide-resistant respiration seems to be widespread in higher plant tissues. Cyanide prevents flow of electron from Cyt  $a_3$  to oxygen, so called ETC inhibitor. In these plant tissues resistance is due to, a branch point in the ETS preceeding the highly cyanide-sensitive cytochromes. The tissues lacking this branch point, or alternate pathway and blockage of cytochromes by cyanide, inhibits the electron flow.

### Significance

(i) The role of alternative pathway is that it may provide a means for the continued oxidation of  $NADH$  and operation of the tricarboxylic acid cycle, even though ATP may not be sufficiently drained off.

(ii) It is significant in respiratory climacteric of ripening fruits and leads to the production of hydrogen peroxide and super oxide, which in turn enhances the oxidation and breakdown of membranes.

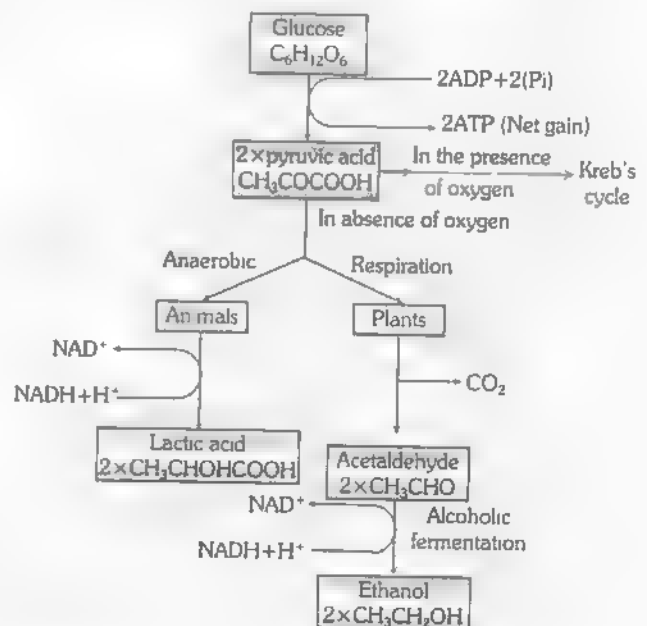
(iii) Necessary activities in the ripening process because peroxides are necessary for ethylene biosynthesis.

## Anaerobic respiration

Anaerobic respiration first studied by Kostychev (1902), Anaerobic respiration is an enzyme-controlled, partial break down of organic compounds (food) without using oxygen and releasing only a fraction of the energy. It is also called intra-molecular respiration (Pfluger, 1875). Anaerobic respiration occurs in the roots of some water-logged plants, certain parasitic worms (*Ascaris* and *Taenia*), animal muscle and some microorganisms (bacteria, moulds). In microorganisms anaerobic respiration is often called fermentation. Fermentation or anaerobic respiration is completed in cytoplasm.

Higher organism like plants can not perform anaerobic respiration for long. It is toxic because accumulation of end products, insufficient amount of available energy and causes stoppage of many active process.

**Process of anaerobic respiration :** In this process pyruvate which is formed by glycolysis is metabolised into ethyl alcohol or lactic acid and  $\text{CO}_2$  in the absence of oxygen. Glycolysis occurs in cytoplasm so the site of anaerobic respiration is cytoplasm.



**Fig : 4.4-8 Summary of anaerobic respiration pathways**

(1) **Formation of ethyl alcohol** : When oxygen is not available, yeast and some other microbes convert pyruvic acid into ethyl alcohol



(2) **Production of lactic acid** : In this process hydrogen atoms removed from the glucose molecule during glycolysis are added to pyruvic acid molecule and thus lactic acid is formed.

Lactic acid is produced in the muscle cells of human beings and other animals.

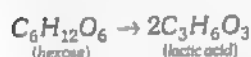
**Pasteur effect :** The process may be defined as "the inhibition of sugar breakdown due to the presence of oxygen under aerobic condition" and the reaction is called Pasteur reaction. Dixon (1937) stated that the Pasteur effect is the action of oxygen in checking the high rate of loss of carbohydrate and in suppressing or diminishing the accumulation of products of fermentation."

**Fermentation :** Fermentation is a kind of anaerobic respiration carried out by microorganisms fungi and bacteria. In microorganism the term anaerobic respiration is replaced by fermentation (Cruickshank, 1897) ; which is known after the name of its major product, e.g., alcohol fermentation, lactic acid fermentation.

(1) **Butyric acid fermentation** : It occurs in bacteria *Clostridium butyricum*.



(2) **Lactic acid fermentation** : It occurs in lactic acid bacteria and muscles.



(3) **Acetic acid fermentation** : It occurs in acetic acid bacteria.



### Respiratory quotient / Respiration ratio

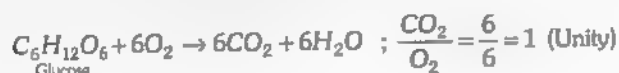
R.Q. is the ratio of the volume of  $\text{CO}_2$  released to the volume of oxygen taken in respiration and is written as

$$\text{R.Q.} = \frac{\text{Volume of CO}_2 \text{ evolved}}{\text{Volume of O}_2 \text{ absorbed}} = \frac{\text{CO}_2}{\text{O}_2}$$

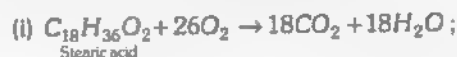
R.Q. is usually measured by Ganong's respirometer.

The value of R.Q. at compensation point is zero.

(1) When carbohydrates are the respiratory substrate (=germinating wheat, oat, barley, paddy grains or green leaves kept in dark or tubers, rhizomes, etc.)



(2) When fats are the respiratory substrate (=germinating castor, mustard, linseed, til seeds) for fatty substances R.Q. is generally less than one .



$$\frac{\text{CO}_2}{\text{O}_2} = \frac{18}{26} = 0.7 \text{ (Less than unity)}$$

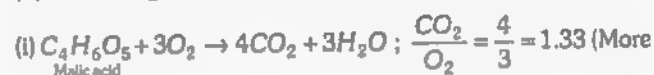


$$\frac{CO_2}{O_2} = \frac{102}{145} = 0.7 \text{ (Less than unity)}$$

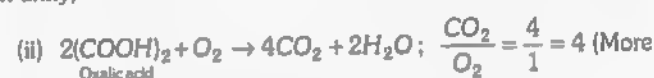
(3) When protein are the respiratory substrate  
(=germinating gram, pea, bean, mung seeds)

value of R.Q. is less than unity (0.5-0.9).

**(4) When organic acids are the respiratory substrate**



than unitv)



than unity)

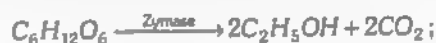
Some other organic acids and their R.Q. are – Succinic acid (1.14), Tauric acid (1.6) and Acetic acid (1).

(5) When there is incomplete oxidation of carbohydrates (In the respiration of succulents i.e., *Bryophyllum*, *Opuntia*).



$$\frac{CO_2}{O_2} = \frac{0}{3} = 0 \text{ (Zero)}$$

(6) **Respiration in the absence of  $O_2$**  (in anaerobic respiration)



$$\frac{CO_2}{O_2} = \frac{2}{0} = \infty \text{ (Infinite)}$$

### Factors affecting rate of respiration

Many external and internal factors affecting the rate of respiration are as follows :

### (1) External factors

(ii) **Temperature :** With every  $10^{\circ}\text{C}$  rise of temperature from  $0^{\circ}\text{C}$  to  $30^{\circ}\text{C}$  the rate of respiration increases 2 to 2.5 times (i.e., temperature coefficient ( $Q_{10}^{\circ}$ ) is = 2 to 2.5), following Vant Hoff's Law. Maximum rate of respiration takes place at  $30^{\circ}\text{C}$ , there is an initial rise, soon followed by a decline. Higher the temperature above this limit, more is the initial rise but more is the decline and earlier is the decline in the rate of respiration. Probably this is due to denaturation of enzymes at high temperature.

Below 0°C the rate of respiration is greatly reduced although in some plants respiration takes place even at -20°C. Dormant seeds kept at -50°C survive.

(ii) **Supply of oxidisable food** : Increase in soluble food content readily available for utilization as respiratory substrate, generally leads to an increase in the rate of respiration upto a certain point when some other factor becomes limiting.

(iii) **Oxygen concentration of the atmosphere** : The amount of oxygen in the environment of plants is increased or reduced upto quite low values the rate of respiration is not effected. On decreasing the amount of oxygen to 1.9% in the environment aerobic respiration become negligible (extinction point of aerobic respiration) but anaerobic respiration takes place.

(iv) **Oxygen poisoning** : The significant fall in respiration rate was observed in many tissues in pure  $O_2$ , even at N.T.P. This inhibiting effect was also observed in green peas when they are exposed to pure oxygen exerting a pressure of 5 atm- the respiration rate fall rapidly. The oxygen poisoning effect was reversible, if the exposure to high oxygen pressure was not too prolonged.

(v) **Water** : With increase in the amount of water the rate of respiration increases. In dry seeds, which have 8-12% of water the rate of respiration is very low but as the seeds imbibe water the respiration increases. As water is necessary for activity of enzymes.

(vi) **Light** : Respiration takes place in night also which shows that light is not essential for respiration. But light effects the rate of respiration indirectly by increasing the rate of photosynthesis due to which concentration of respiratory substrates is increased. More the respiratory substrate more is the rate of respiration.

(vii) **Carbon dioxide ( $CO_2$ )** : If the amount of  $CO_2$  in the air is more than the usual rate of respiration is decreased. Germination of seeds is reduced and rate of growth falls down. Heath, (1950) has shown that the stomata are closed at higher conc. of  $CO_2$ , due to which oxygen does not penetrate the leaf and rate of respiration is lowered.

(viii) **Inorganic salts** : The chlorides of alkali cations of Na and K, as also the divalent cations of Li, and Ca and Mg, generally increase the rate of respiration as measured by the amount of  $CO_2$  evolved. Monovalent chlorides of K and Na increases the rate of respiration, while divalent chlorides of Li, Ca and Mg causes less increase in respiration.

(ix) **Injury and effects of mechanical stimulation** : Wounding or injury almost invariably results in an increase in the rate of respiration.

(x) **Effect of various chemical substances** : Certain enzymatic inhibitors like cyanides, azides, carbon monoxide, iodoacetate, malonate etc. reduce the rate of respiration even if they are present in very low concentration

However, various chemical substances such as chloroform, ether, acetone, morphine, etc., brings about an increase in respiratory activity.

(xi) **Pollutants** : High concentration of gaseous air pollutants like  $SO_2$ ,  $NO_x$  and  $O_3$  inhibit respiration by damaging cell membrane. These gaseous pollutant causes increase in pH which in turn affects the electron transport system thus inhibiting respiration.

Heavy metal pollutant like lead (Pb) and cadmium (Cd) inhibit respiration by inactivating respiratory enzymes.

## (2) Internal Factors

(i) **Protoplasm** : The meristematic cells (dividing cells of root and shoot apex) have more protoplasm than mature cells. Hence, the meristematic cells have higher rate of respiration than the mature cells. Respiration rate high at growing regions like floral and vegetative buds, germinating seedlings, young leaves, stem and root apices.

(ii) **Respiratory substrate** : With the increase in the amount of respiratory substrate, the rate of respiration increases.

## Tips & Tricks

✚ Lavoisier (1783) found that respiration in animals involves intake of  $O_2$  and liberation of  $CO_2$ . Dutochet is belived to have used the term of respiration for the first time, while book "cellular respiration" was written by Meldrum.

✚ Energesis : An old term of respiration.

✚ One glucose molecule contain about 686 K cal of energy and 38 ATP molecules provide 288.8 K cal of energy. Therefore about 40% (288.8/686) energy of the glucose molecule is gained during aerobic breakdown and the rest is lost as heat.

✚ Glucose oxidation is very rapid process of complete oxidation of a glucose molecules takes only one second.

✚ Glucose 6-phosphate called Rohinsonester, fructose 6-phosphate called Newberg's ester and fructose 1,6-diphosphate called Harden and Young's ester.

✚ Phosphofructokinase called regulatory enzyme of glycolysis, it is inhibited by high concentration of ATP and is stimulated by ADP and Pi

✚ Formation of 1,3-diphosphoglyceraldehyde called non enzymatic phosphorylation.

✚ Krebs cycle is the central pathway of the cell respiration where the catabolic pathways converge upon it an anabolic pathways diverge from it, so called amphibolic pathway.

✚ Acetyl Co-A, also called active acetate

✚ In Kreb's cycle, acetyl CoA undergoes two decarboxylation and four dehydrogenation. Krebs cycle catabolises about 80-90% of glucose.

✚ ATP discovered by Karl Lohmann (1929), term was coined by Lohmann (1931) while ATP cycle was discovered by Lipmann (1941).

✚ Allosteric inhibition or negative feedback by accumulation of  $NADH_2$

✚ Cytochromes were discovered by MacCunn and term cytochrome given by K.P.Kailin.

✚ Ganong's respiroscope is used to demonstrate production of  $CO_2$  during aerobic respiration.

Iron-Sulphur is the component of ETC (complex I, II, III) and helps in transfer of electrons from FMN<sub>2</sub> to coenzyme Q. Thus, deficiency of iron directly affects ETC or oxidative phosphorylation.

Cytochromes are Iron-containing (Iron porphyrin protein) electron transferring (electrons picked up and released by Fe) except cytochrome a<sub>3</sub>. Cytochrome a<sub>3</sub> contains both Iron and Copper, in this Fe picks the electrons and through Cu it hands over electron to oxygen, so cytochrome a<sub>3</sub> called terminal electron donor.

#### ETC Inhibitors

(i) Dinitrophenol (2,4-DNP) : It prevents synthesis of ATP from ADP because it directs electrons from CoQ to O<sub>2</sub>.

(ii) Cyanide : It prevents flow of electrons from Cyt a<sub>3</sub> to oxygen.

(iii) Carbon monoxide : It functions like cyanide.

(iv) Antimycin A: Transfer of electron from Cyt b to Cyt c<sub>1</sub> is prevented.

(v) Rotenone : It checks flow of electrons from NADH /FADH<sub>2</sub> to CoQ.

Action of ATPase needed Na<sup>+</sup> and K<sup>+</sup>.

Amount of energy released in ETC :

(i) 12.2 Kcal during transfer of electrons from NAD to FMN.

(ii) 15.2 Kcal during transfer of electrons from Cyt b to Cyt c.

(iii) 24.5 Kcal during transfer of electrons from Cyt a to Cyt a<sub>3</sub>.

Glyoxylate cycle is called adaptation of Krebs's cycle.

Effect of cyanide poisoning can be minimised by immediate supply of ATP.

In prokaryotes aerobic cell respiration of glucose always produces 38 ATP molecules, as NADH<sub>2</sub> molecules formed during glycolysis are not enter the mitochondria.

Pentose phosphate pathway called connective link between photosynthesis and fat synthesis.

The potato growing in hilly areas are bigger in size because in hilly areas temperature is low. Respiration decreases on low temperature therefore in potato complete oxidation of carbohydrate not takes place and carbohydrate/ starch in potato tuber accumulates and increases the size.

The R.Q. at compensation point =  $\frac{CO_2}{O_2}$  = Zero (CO<sub>2</sub> and O<sub>2</sub> equal at compensation point).

Temperature affects germinating seeds because hydration makes enzyme more sensitive to temperature.

Glucose before converting glycogen in muscles and liver converted into glucose 6-phosphate needed ATP. Glycogen also before utilization converted into glucose 6-phosphate process called glycogenolysis.

Thiamine pyrophosphate is the active form of vitamin B<sub>1</sub> (Thiamine) work as coenzyme of pyruvate carboxylase dehydrogenase.

Climacteric fruits : Those fruits which show a high rate of respiration during their ripening e.g., Apple, Banana. In these fruits rise of respiration called climacteric rise.

Aldolase and triose phosphate isomerase enzyme are common for EMP and C<sub>3</sub> pathway.

In fermentation yeast secretes the enzyme zymase.

Universal hydrogen acceptor in NAD.



## Ordinary Thinking

### Objective Questions

#### Anaerobic respiration

- The energy releasing process in which the substrate is oxidised without an external electron acceptor is called  
[CBSE PMT 2008; CBSE PMT (Pre.) 2010]

Or

Lactic acid converted into alcohol in process called  
[HPMT 2005; DPMT 2007]

- Aerobic respiration
  - Glycolysis
  - Fermentation
  - Photorespiration
- During anaerobic conditions, the rate of glycolysis increases is called as

Or

The process by which there is inhibition of aerobic respiration by atmospheric O<sub>2</sub> is  
[DPMT 2004]

- Compensation point
  - Extinction point
  - Warburg effect
  - Pasteur effect
- How many ATP molecules are obtained from fermentation of 1 molecule of glucose  
[WB JEE 2009; KCET 2011]
  - In anaerobic respiration, from one glucose molecule how many net ATP molecules are formed
  - Pasteur effect is concerned with the shifting of environmental conditions from  
[KCET 2001]
  - The incomplete breakdown of sugars in anaerobic respiration results in the formation of

Or

End product of anaerobic respiration is  
[AFMC 1995; RPMT 1999]

Or

The end products of fermentation when sugars are used as raw material  
[CBSE PMT 1997]

- Fructose and water
  - Glucose and CO<sub>2</sub>
  - Alcohol and CO<sub>2</sub>
  - Water and CO<sub>2</sub>
- Which of the following plant is widely accepted to respire in absence of oxygen  
[MHCET 2003; MP PMT 2004]
  - Cyanide resistant pathway is  
[DPMT 2004]
  - When a molecule of pyruvic acid is subjected to anaerobic oxidation and forms lactic acid, there is
  - During cellulose fermentation by anaerobic bacteria in rumen and reticulum, cellulose is majorly converted into

- Lactic acid
- Ethyl alcohol
- Volatile fatty acids
- CO<sub>2</sub>

11. Fermentation is [AFMC 1997, 99; MP PMT 2003; BHU 2006; Odisha JEE 2011]  
 (a) Anaerobic respiration after glycolysis  
 (b) Incomplete oxidation of carbohydrates  
 (c) Complete oxidation of carbohydrates  
 (d) None of the above
12. Which of the following minerals activate the enzymes involved in respiration [Kerala PMT 2011]  
 (a) Nitrogen and phosphorus  
 (b) Magnesium and manganese  
 (c) Potassium and calcium  
 (d) Sulphur and iron  
 (e) Copper and boron
13. During anaerobic respiration in yeast [CPMT 1992; BVP 2002; AIEEE Pharmacy 2003]  
 (a) Water and  $\text{CO}_2$  are end products  
 (b)  $\text{CO}_2$ ,  $\text{C}_2\text{H}_5\text{OH}$  and energy are end products  
 (c)  $\text{H}_2\text{S}$ ,  $\text{C}_6\text{H}_{12}\text{O}_6$  and energy are the end products  
 (d)  $\text{H}_2\text{O}$ ,  $\text{CO}_2$  and energy are the only end products
14. Fermentation is represented by the equation [MP PMT 1994, 96]  
 (a)  $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + 673 \text{ k cal}$   
 (b)  $\text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 2\text{C}_2\text{H}_5\text{OH} + 2\text{CO}_2 + 18 \text{ k cal}$   
 (c)  $6\text{CO}_2 + 12\text{H}_2\text{O} \xrightarrow[\text{Chlorophyll}]{\text{Light}} \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{H}_2\text{O} + 6\text{O}_2$   
 (d)  $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$
15. During anaerobic respiration the conversion of pyruvate into acetaldehyde, along with co-enzyme TPP, the cofactor required is [MHCET 2015]  
 (a)  $\text{Mg}^{++}$  (b)  $\text{Mn}^{++}$   
 (c)  $\text{Fe}^{++}$  (d)  $\text{Zn}^{++}$
16. Continuous addition of sugars in 'fed batch' fermentation is done to [CBSE PMT (Pre.) 2011]  
 (a) Degrade sewage (b) Produce methane  
 (c) Obtain antibiotics (d) Purify enzymes
17. Anaerobic products of fermentation are [CBSE PMT 1996; JIPMER 2001]  
 (a) Alcohol and lipoprotein  
 (b) Ether and nucleic acid  
 (c) Protein and nucleic acid  
 (d) Alcohol, lactic acid and similar compound
18. During lactic acid fermentation, ..... [KCET 2010; CBSE PMT 2014]  
 (a)  $\text{O}_2$  is used,  $\text{CO}_2$  is liberated  
 (b) Neither  $\text{O}_2$  is used, nor  $\text{CO}_2$  is liberated  
 (c)  $\text{O}_2$  is used,  $\text{CO}_2$  is not liberated  
 (d)  $\text{O}_2$  is not used,  $\text{CO}_2$  is liberated
19. Anaerobic respiration was first of all reported by  
 (a) Maguene (b) Kostychev  
 (c) Klein (d) Pfeffer
20. What is the total gain of energy during anaerobic respiration  
 (a) One molecule of ATP (b) Two molecules of ATP  
 (c) Four molecules of ATP (d) Eight molecules of ATP
21. In fermentation, yeast secretes one of the following enzyme  
 (a) Invertase (b) Zymase  
 (c) Dehydrogenase (d) Anolase
22. Select a suitable name for the following process  
 $\text{C}_6\text{H}_{12}\text{O}_6 + 2\text{ADP} + 2\text{P}_i \rightarrow 2\text{C}_2\text{H}_5\text{OH} + 2\text{ATP} + 2\text{CO}_2 \uparrow$  [KCET 2012]  
 (a) Alcoholic fermentation (b) Photorespiration  
 (c) Lactate fermentation (d) Aerobic respiration

### Introduction and types of respiration

1. Which of the following is the phosphorylating unit [AFMC 2000]  
 (a) Oxysome (b) Mesosome  
 (c) Peroxisome (d) Mitochondria
2. Aerobic respiratory pathway is appropriately termed [NCERT; CBSE PMT 2009]  
 (a) Catabolic (b) Parabolic  
 (c) Amphibolic (d) Anabolic
3. Which of the following show higher rate of respiration [NCERT]  
 (a) Collenchyma (b) Leaf  
 (c) Dry seeds (d) Germinating seeds
4. How many ATP molecules will be generated in a plant system during complete oxidation of 40 moles of glucose [WB JEE 2012]  
 (a) 190 (b) 380  
 (c) 1520 (d) 3040
5. Which one is product of aerobic respiration [WB JEE 2009]  
 (a) Malic acid (b) Ethyl alcohol  
 (c) Lactic acid (d) Pyruvic acid
6. The energy consumed during the conversion of ADP into ATP is [Pb. PMT 2000]  
 (a) 73000 cal/mole (b) 686000 cal/mole  
 (c) 8000 cal/mole (d) 7300 cal/mole
7. Which of the substrate is used in protoplasmic respiration  
 (a) Fat (b) Carbohydrate  
 (c) Protein (d) All the above
8. How much of the energy released during aerobic respiration is approximately conserved in the form of ATP [MHCET 2015]  
 (a) 20% (b) 40%  
 (c) 60% (d) 100%
9. Heat energy of plants is measured in [MP PMT 1996]  
 (a) Grams (b) Pounds  
 (c) Decibels (d) Calories
10. Chemiosmotic theory of ATP synthesis in the chloroplasts and mitochondria is based on [CBSE PMT 1997, 2005; KCET 2012]  
 (a) Proton gradient (b) Accumulation of K ions  
 (c) Accumulation of Na ions (d) Membrane potential

11. Which of the option is correct for photorespiration

[GUJCET 2014]

- (a) In chloroplast, glycerate forms glycine
- (b) In peroxisome, glycerate forms phosphoglycolate
- (c) In mitochondrion, glycine forms serine
- (d) In bundle sheath, serine form glycine

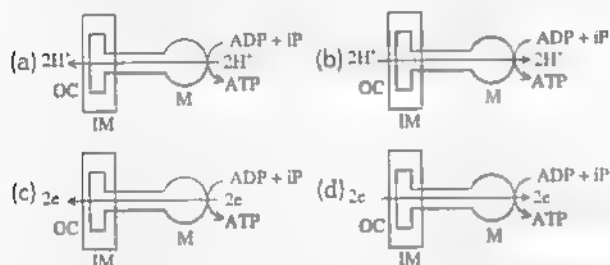
12. Which diagram represents the ATP synthesis in mitochondria through chemiosmosis

IM = Inner membrane

M = Matrix

O, C = Outer Chamber

[NCERT]



13. In carbon dioxide reduction ATP is

[MP PMT 2005]

- (a) Used
- (b) Unused
- (c) May be used or not used
- (d) None

14. In submerged hydrophytes entry of  $\text{CO}_2$  is through

[DPMT 2004]

- (a) Epidermis as dissolved  $\text{CO}_2$
- (b) Epidermis as carbonates only
- (c) Epidermis as bicarbonates only
- (d) Both (b) and (c)

15. The three boxes in this diagram represent the three major biosynthetic pathways in aerobic respiration. Arrows represent net reactants or products



Arrow numbered 4, 8 and 12 can all be

[NEET 2013]

- (a)  $\text{FAD}^+$  or  $\text{FADH}_2$
- (b)  $\text{NADH}$
- (c)  $\text{ATP}$
- (d)  $\text{H}_2\text{O}$

16. Respiration differs from the process of combustion in the fact that

- (a) All the energy stored in glucose is released at once due to combustion and enzymes are involved
- (b) All energy stored in glucose is gradually released due to combustion
- (c) Comparatively large quantity of energy is produced due to combustion
- (d) The carbohydrates act as the combustion substance

17. Adenosine diphosphate contains

[CPMT 1995]

- (a) One high energy bond
- (b) Two high energy bond
- (c) Three high energy bond
- (d) Four high energy bond

18. "Mitchell's chemiosmotic theory" belongs to

- (a) Krebs's cycle
- (b) Oxidative phosphorylation
- (c) Glycolysis
- (d) None of the above

19. Which of the following is involved in the catalysis of link reaction during aerobic respiration

[DPMT 2004]

- (a) Vitamin A
- (b) Vitamin  $\text{B}_1$
- (c) Vitamin  $\text{B}_6$
- (d) Vitamin K

20. Ganong's respiroscope is used to demonstrate.....

[KCET 2004]

- (a) Production of carbon dioxide during aerobic respiration
- (b) Production of heat during aerobic respiration
- (c) Evolution of oxygen during photosynthesis
- (d) Evolution of carbon dioxide during fermentation

21. ATP was discovered by

[KCET 2004]

- (a) Blackman
- (b) Bowman
- (c) Lipmann
- (d) Karl Lohman

22. Mechanism of aerobic respiration was discovered by

[AFMC 2004]

- (a) Krebs's
- (b) Calvin
- (c) Hatch and Slack
- (d) Pasteur

23. Cell respiration (Internal Respiration) is carried out by

[CPMT 1998; Odisha JEE 2004; Pb. PMT 2004]

Or

Aerobic respiration which yields maximum ATP molecules is completed on

[BHU 1999]

- (a) Ribosome
- (b) Mitochondria
- (c) Chloroplast
- (d) Golgi bodies

24. In mitochondria, cristae act as sites for

[Pb. PMT 1999; AFMC 2000; CBSE PMT 2000]

- (a) Protein synthesis
- (b) Oxidation-reduction reaction (respiration)
- (c) Breakdown of macromolecules
- (d) Phosphorylation of flavoproteins

25. Which of the following forms the connecting link between glycolysis and Krebs's cycle

[Kerala CET 2003; Wardha 2005]

- (a) Glucose
- (b) Ethyl alcohol
- (c) Lactic acid
- (d) Pyruvic acid

26. Enzymes related with cristae are related with

[CPMT 1996]

- (a) Anaerobic respiration
- (b) Aerobic respiration
- (c)  $\text{CO}_2$  formation
- (d) Reduction of pyruvic acid

27. Which of the following is a more accurate statement about respiration

- (a)  $\text{O}_2$  must always be available for respiration
- (b)  $\text{O}_2$  combines with carbon to form  $\text{CO}_2$
- (c)  $\text{O}_2$  combines with hydrogen to form  $\text{H}_2\text{O}$
- (d) Air is inhaled and exhaled only from stomata

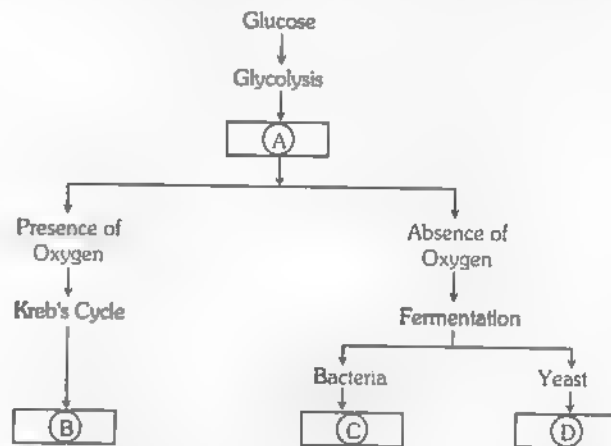
28. In the respiratory process, energy is released and is used to synthesise energy rich molecules of ATP from ADP, thereby storing energy for future use. This process of output of these molecules in the aerobic phase is known as

[DPMT 1993]

- (a) Krebs's cycle
- (b) Glycolysis
- (c) Phosphorylation
- (d) Ornithine cycle



29. How many ATP are formed from  $NADPH^+$  to  $NAD^+$   
[KCET 2000; AFMC 2004; Bihar CECE 2006;  
Kerala PMT 2010; Odisha JEE 2010; J & K CET 2012]  
(a) 2 ATP (b) 3 ATP  
(c) 6 ATP (d) 4 ATP
30. An ATP molecule is structurally most similar to a molecule of  
[Kerala CET 2003; Odisha JEE 2009]  
(a) RNA molecule (b) DNA molecule  
(c) Amino acid (d) Fatty acid
31. Aerobic respiration is called  
(a) Fermentation (b) Chemosynthesis  
(c) Bio-oxidation (d) Photorespiration
32. Which of the following is utilized first in respiration  
[BVP 2003]  
(a) Fat (b) Protein  
(c) Sucrose (d) Hexose
33. Degradation of sugar and fat to Acetyl CoA will not take place if the following organelle is not present in a eukaryotic cell  
[AIEEE Pharmacy 2003]  
(a) Golgi apparatus (b) Mitochondrion  
(c) Ribosome (d) Nucleus
34. Salt respiration is also called as [J & K CET 2002]  
(a) Anion respiration (b) Cation respiration  
(c) Photorespiration (d) None of the above
35. Leaves of annual plants obtain  $O_2$  through  
(a) Cell walls (b) Cuticle and leaf scars  
(c) Stomata (d) Lenticels
36. Respiratory exchange in seeds occur through  
(a) Testa (b) Stomata  
(c) Micropyle (d) Hilum
37. The aerobic respiration yields [MHCET 2002]  
(a)  $8NADH_2$ ,  $2FADH_2$ , 2ATP  
(b)  $10NADH_2$ ,  $2FADH_2$ , 38ATP  
(c)  $12NADH_2$ , 30ATP,  $H_2O$   
(d)  $10NADH_2$ ,  $2FADH_2$ , 2GTP, 2ATP
38. Protein is used as respiratory substrate only when  
(a) Carbohydrates are absent  
(b) Fats are absent  
(c) Both exhausted  
(d) Fats and carbohydrates are abundant
39. Which of the scientific paper would you assign to plant physiology  
(a) Evergreen forest of India  
(b) Embryo culture of plants  
(c) Respiratory activities in plants  
(d) Cell and cell division
40. Chemiosmotic mechanism of ATP synthesis was proposed by [MHCET 2001; KCET 2011]  
(a) Warberg (b) Dickens  
(c) Krebs (d) P. Mitchell
41. The following is a simplified scheme showing the fate of glucose during aerobic and anaerobic respiration. Identify the end products that are formed at stages indicated as A, B, C and D. Identify the correct option from those given below [KCET 2006]



- (a) A = carbon dioxide and water, B = pyruvic acid, C = ethyl alcohol and carbon dioxide, D = lactic acid  
(b) A = pyruvic acid, B = carbon dioxide and water, C = lactic acid, D = ethyl alcohol and carbon dioxide  
(c) A = pyruvic acid, B = carbon dioxide and water, C = ethyl alcohol and carbon dioxide, D = lactic acid  
(d) A = pyruvic acid, B = ethyl alcohol and carbon dioxide, C = lactic acid, D = carbon dioxide and water

42. The rate of respiration could be checked by  
(a) Malonate (b)  $CO_2$   
(c) Chloroform and cyanides (d) All the above
43. If a starved plant is provided with glucose, the rate of respiration would  
(a) Decrease (b) Increase  
(c) Become constant (d) First rise and then fall
44. The high-energy bonds of ATP are between [AIIMS 2001]  
(a) C-C (b) C-O  
(c) C-N (d) O-P
45. Respiration initiated in chloroplasts and occurs in light is called [J & K CET 2005]  
(a) Aerobic respiration (b) Anaerobic respiration  
(c) Photorespiration (d) Fermentation
46. Which of the following is formed during respiration [MP PMT 1999]  
(a)  $O_2$  (Oxygen) (b)  $CO_2$  (Carbon dioxide)  
(c)  $NO_2$  (Nitrogen dioxide) (d)  $SO_2$  (Sulphur dioxide)
47. From substrate level phosphorylation ATP are produced [BHU 2000]  
(a) 2 (b) 6  
(c) 10 (d) 8
48. The net gain of energy, from one molecule of sucrose in aerobic respiration, is [CBSE PMT 2001]  
(a) 18 ATP (b) 38 ATP  
(c) 60 ATP (d) 76 ATP

49. Common immediate source of energy in cellular activity or Energy currency of the cell is [CPMT 1994; MP PMT 2002]

Or

To a living organism which of the following has the greater amount of available energy per molecule

- (a) DNA (b) ATP  
(c) RNA (d) NAD
50. Make suitable pairing
- (A) Glycolysis (a) Mitochondria  
(B) Krebs's cycle (b) Cytoplasmic matrix  
(C) Electron transport chain

[RPMT 1997]

- (a) Aa, Ba, Cb (b) Ab, Ba, Ca  
(c) Aa, Bb, Cb (d) Ab, Bb, Ca

51. The net gain of energy from one gram molecule of glucose during aerobic respiration is

[CPMT 1996, 2002; CBSE PMT 1999; BHU 2000; KCET 2001; RPMT 2002; MP PMT 2012; AIIMS 2012]

Or

Net gain of ATP in prokaryotes from a molecule of glucose when oxidized is [RPMT 2005]

- (a) 2 ATP (b) 36 ATP  
(c) 38 ATP (d) 15 ATP

52. If the  $\text{CO}_2$  content of atmosphere is as high as 300 parts per million

- (a) All plants will be killed  
(b) The plants would not grow properly  
(c) Plants would grow for sometime and then die  
(d) The plants would thrive well

53. Different steps in respiration are controlled by

[DPMT 1992; CPMT 2002]

- (a) Auxin (b) Sugar  
(c) Enzyme (d) Kinetin

54. Highest calories is obtained from [CPMT 1996]

- (a) Fats (b) Proteins  
(c) Carbohydrates (d) Vitamins

55. Aerobic respiration of glucose produces energy

[MP PMT 1993]

- (a) 637 kcal (b) 640 kcal  
(c) 673 kcal (d) 693 kcal

56. Cytochrome is related to

- (a) Cellular digestion (b) Protein synthesis  
(c) Cell division (d) Cellular respiration

57. Energy given by one molecule of ATP is [MP PMT 2005]

- (a) 7.3 kcal (b) 721 kcal  
(c) 760 kcal (d) 1000 kcal

58. Respiration is an [NCERT]

- (a) Endothermic process (b) Exothermic process  
(c) Anabolic process (d) Endergonic process

59. Who among the following can be said to be the "Father of Indian Physiology"

- (a) B.P. Pal (b) K.C. Mehta  
(c) M.S. Swaminathan (d) J.C. Bose

60. The energy yield as a result of total oxidation of one glucose molecule during cellular respiration is to convert

[CBSE PMT 1992]

- (a) 38 molecules of ADP into 38 molecules of ATP  
(b) 30 molecules of ADP into 30 molecules of ATP  
(c) 36 molecules of ADP into 36 molecules of ATP  
(d) 32 molecules of ADP into 32 molecules of ATP

61. Cut surfaces of fruit and vegetables often become dark because

- (a) Dirty knife makes it dark  
(b) Oxidation of tannic acid in the presence of trace of iron from the knife makes it dark  
(c) Dust of the air makes it dark  
(d) None of the above

62. Oxidative phosphorylation occurs during the process of

[MP PMT 1994, 98; HPMT 2005]

- (a) Protein synthesis (b)  $\text{N}_2$  fixation  
(c) Respiration (d) Transpiration

63. The connecting link among glycolysis, Krebs's cycle and beta-oxidation of fatty acid is [MP PMT 1994, 98, 2001;

CBSE PMT 1997, 2000; BHU 2000; CPMT 2001; BVP 2001; MHCET 2004; DUMET 2010]

Or

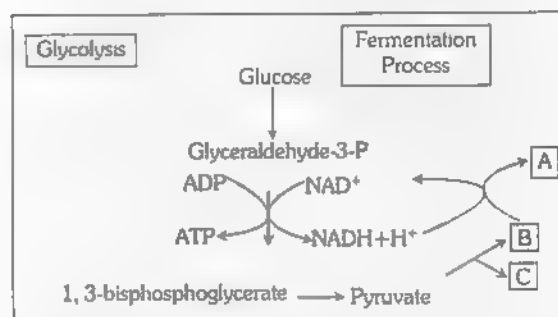
Which of the metabolites is common to respiration mediated breakdown of fats, carbohydrates and proteins [NEET 2013]

- (a) Pyruvic acid (b) Acetyl CoA  
(c) Acetaldehyde (d) Citric acid

### Glycolysis

1. Choose the correct combination of labelling the molecules involved in the pathway of anaerobic respiration in yeast

[Kerala PMT 2008; KCET 2015]



- (a) A – Ethanol B –  $\text{CO}_2$  C – Acetaldehyde  
(b) A –  $\text{CO}_2$  B – Ethanol C – Acetaldehyde  
(c) A –  $\text{CO}_2$  B – Acetaldehyde C – Ethanol  
(d) A – Acetaldehyde B –  $\text{CO}_2$  C – Ethanol  
(e) A – Ethanol B – Acetaldehyde C –  $\text{CO}_2$

2. In which of the following reaction of glycolysis, a molecule of water is removed from the substrate [Kerala PMT 2008]  
 (a) Fructose - 6 - phosphate  $\rightarrow$  fructose 1, 6 - bisphosphate  
 (b) 3 - phosphate glyceraldehyde  $\rightarrow$  1, 3-bisphosphoglyceric acid  
 (c) PEP  $\rightarrow$  pyruvic acid  
 (d) 2 - Phosphoglycerate  $\rightarrow$  PEP  
 (e) Glucose  $\rightarrow$  glucose 6 - phosphate
3. Which process does the following equation represent  
 $C_6H_{12}O_6 + 2NAD + 2ADP + 2P_i$   
 $\rightarrow 2CH_3 - CO - COOH + 2NADH_2 + 2ATP$   
 [MHCET 2015]  
 (a) Complete glycolysis  
 (b) Complete aerobic respiration  
 (c) Complete anaerobic respiration  
 (d) Complete fermentation
4. How many ATP are used in glycolysis or For complete phosphorylation of a glucose molecule, how many ATP molecules are required  
 Or  
 The net gain of ATP during glycolysis is [KCET 2007]  
 (a) 4 (b) 2  
 (c) 6 (d) 8
5. Which of the following substances yield less than 4 Kcal/mol when its phosphate bond is hydrolysed [WB JEE 2009]  
 (a) Creatine phosphate (b) ADP  
 (c) Glucose-6-phosphate (d) ATP
6. Which is not true for glycolysis [NCERT; Manipal 2005]  
 (a) End product is  $CO_2$ ,  $H_2O$   
 (b) Substrate level phosphorylation  
 (c) Production of ATP  
 (d) Expenditure of ATP
7. Glycolysis term has originated from Greek words [NCERT; AMU (Med.) 2012]  
 (a) Glycose and lysis (b) Glycos and lysis  
 (c) Glyco and lysis (d) Glucose and lysis
8. Consider the following statements with respect to respiration  
 A. Glycolysis occurs in the cytoplasm of the cell  
 B. Aerobic respiration takes place within the mitochondria  
 C. Electron transport system is present in the outer mitochondrial membrane  
 D.  $C_{51}H_{98}O_5$  is the chemical formula of Tripalmitin, a fatty acid  
 E. Respiratory quotient =  $\frac{\text{Volume of } O_2 \text{ evolved}}{\text{Volume of } CO_2 \text{ consumed}}$   
 Of the above statements [Kerala PMT 2012]  
 (a) A, B, and D alone are correct  
 (b) B, C and D alone are correct  
 (c) C, D and E alone are correct  
 (d) B, D and E alone are correct  
 (e) A, C and E alone are correct
9. Decarboxylation is not involved in [DPMT 2004]  
 (a) Electron transport system (b) Glycolysis  
 (c) Krebs's cycle (d) Alcoholic fermentation
10. Which one is correct sequence in glycolysis [MHCET 2004]  
 (a) G 6-P  $\rightarrow$  PEP  $\rightarrow$  3-PGAL  $\rightarrow$  3-PGA  
 (b) G 6-P  $\rightarrow$  3-PGAL  $\rightarrow$  3-PGA  $\rightarrow$  PEP  
 (c) G 6-P  $\rightarrow$  PEP  $\rightarrow$  3-PGA  $\rightarrow$  3 - PGAL  
 (d) G 6-P  $\rightarrow$  3-PGA  $\rightarrow$  3-PGAL  $\rightarrow$  PEP
11. In glycolysis, during oxidation electrons are removed by [CBSE PMT 2004]  
 (a)  $NAD^+$   
 (b) Molecular oxygen  
 (c) ATP  
 (d) Glyceraldehyde-3-phosphate
12. In glycolytic pathway which of the following steps shows reduction of co-enzyme [Odisha JEE 2010]  
 (a) 1, 3-diphosphoglycerate to 3-phosphoglycerate  
 (b) Glucose 6-phosphate to fructose 6-phosphate  
 (c) Glyceraldehyde 3-phosphate to 1,3-diphosphoglycerate  
 (d) 3-phosphoglycerate to 2-phosphoglycerate
13. First stage in respiration is  
 (a) Aerobic oxidation of pyruvic acid  
 (b) Liberation of  $CO_2$   
 (c) Glycolysis  
 (d) Electron transport system
14. Besides the net gain of 2 ATP molecules in glycolysis which other molecules are simultaneously formed [CPMT 1995]  
 (a)  $FADH_2$  (b)  $NADPH_2$   
 (c)  $NADH_2$  (d)  $FAMH_2$
15. Which of the following is the product of phosphorylation  
 (a) PGA (b) Fructose 1, 6 diphosphate  
 (c) DPGA (d) Pyruvic acid
16. In glycolysis, the end product is [NCERT; CPMT 1996, 2001, 03  
 MP PMT 1996, 2003; KCET 1998; MHCET 2001;  
 PET (Pharmacy) 2013]  
 (a) Protein is converted to glucose  
 (b) Glucose is converted into fructose  
 (c) Starch is converted into glucose  
 (d) Glucose is converted into pyruvic acid
17. Total ATP production during EMP pathway is [CBSE PMT 1990]  
 (a) 24 ATP molecules (b) 8 ATP molecules  
 (c) 38 ATP molecules (d) 6 ATP molecules
18. Glycolysis (EMP Pathway) takes place in [KCET 1994; MP PMT 1996, 2004, 05; BVP 2001;  
 Odisha PMT 2002; RPMT 2002; CPMT 2004;  
 Bihar CECE 2006; Odisha JEE 2008; J & K CET 2012]  
 Or  
 Anaerobic respiration takes place in the [DPMT 1992; MP PMT 2002, 06]  
 (a) Mitochondria  
 (b) Cytoplasm  
 (c) Both mitochondria and cytoplasm  
 (d) Vacuole

19. Which one of the following is the first step of glycolysis [NCERT; DPMT 2004]  
 (a) Breakdown of glucose  
 (b) Phosphorylation of glucose  
 (c) Conversion of glucose into fructose  
 (d) Dehydrogenation of glucose
20. Glycolysis occurs in [NCERT; BVP 2001; AFMC 2003]  
 (a) Generally in all the cells (b) In only eukaryotes  
 (c) Only in prokaryotes (d) Only in higher animals
21. The number of molecules of pyruvic acid formed from one molecule of glucose at the end of glycolysis is  
 (a) 1 (b) 2  
 (c) 3 (d) 4
22. What is the other name of glycolysis [Pune CET 1998; CPMT 1998]  
 (a) EMP pathway (b) TCA pathway  
 (c) HMS pathway (d) None of the above
23. During respiration ..... [GUJCET 2015]  
 (a) 2 PGAL during glycolysis and none of the PGAL produced in Kreb's cycle  
 (b) 2 PGAL during glycolysis and 4 Pyruvic acid are produced in Kreb's cycle  
 (c) 2 PGAL during glycolysis and 2 Pyruvic acid are produced in Kreb's cycle  
 (d) PGAL is not produced during respiratory events
24. During respiration, pyruvic acid is formed by [BHU 1995; MP PMT 2011]

Or

The first phase in the breakdown of glucose in animal cells is [BVP 2002; AIEEE Pharmacy 2004]

- (a) Glycolysis (b) Kreb's cycle  
 (c) HMP pathway (d) None of the above
25. The common phase between aerobic and anaerobic respiration is called [NCERT; MP PMT 1992, 2009; BHU 2008]  
 (a) Tricarboxylic acid cycle  
 (b) Oxidative phosphorylation  
 (c) Embden, Meyerhof, Parnas cycle (Glycolysis)  
 (d) Kreb's cycle
26. The formula for the process of glycolysis is [KCET 1994]  
 (a)  $C_6H_{12}O_6 \rightarrow 2C_3H_4O_3 + 4H$   
 (b)  $C_6H_{12}O_6 + 6CO_2 \rightarrow 6CO_2 + 6H_2O$   
 (c)  $6H_2O + 6CO_2 \rightarrow C_6H_{12}O_6 + 6O_2$   
 (d) None of these
27. Which group of the following scientists discovered the EMP pathway of glycolysis [NCERT; MP PMT 1995; BVP 2002]  
 (a) Embden, Meyerhof and Parnas  
 (b) Emerson, Hoffman and Peterson  
 (c) Embden, Morrison and Pitcher  
 (d) Avery, McLeod and McCarthy

28. Which one of the following products is formed during glycolysis of glucose [MP PMT 1995, 2000, 02; AIIMS 2002]  
 (a) Pyruvic acid (b) Carbon dioxide  
 (c) Citric acid (d) Ethanol
29. Column I contains some enzymes and Column II contains reactions. Match them properly and choose the right answer [MP PMT 1996; AIIMS 1999; Pb PMT 1999, 2000]

	Column I		Column II
A.	Hexokinase	1.	Conversion of fructose-6-phosphate to fructose-1,6-diphosphate
B.	Triose Phosphate dehydrogenase	2.	Conversion of glucose to glucose-6-phosphate
C.	Phosphoglyceromutase	3.	Conversion of 1, 3-diphosphoglyceraldehyde to 1, 3-diphosphoglyceric acid
D.	Phosphofructokinase	4.	Conversion of 3-phosphoglyceric acid to 2-phosphoglyceric acid

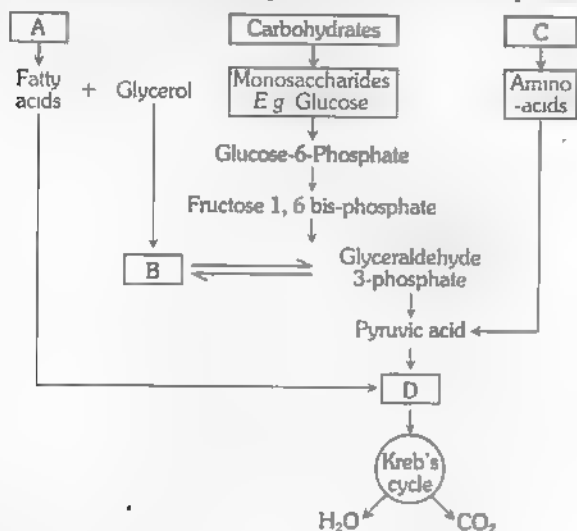
- (a) A-1, B-2, C-3, D-4  
 (b) A-2, B-3, C-4, D-1  
 (c) A-2, B-1, C-3, D-4  
 (d) A-1, B-5, C-2, D-4
30. ATP formation in glycolysis is [AMU (Med.) 2006; MP PMT 2012]  
 (a) Oxidative phosphorylation  
 (b) Photophosphorylation  
 (c) Reductive phosphorylation  
 (d) Substrate level phosphorylation
31. Given below are some reactions and the enzymes involved. Identify the correct pairs

I		II	
1.	Fructose 1,6 diphosphate $\rightarrow$ 3 PGAL + DHAP	A.	Enolase
2.	Citrate $\rightarrow$ Cis - aconitate	B.	Thiokinase
3.	Succinyl Co. A $\rightarrow$ Succinate	C.	Aconitase
4.	2 PGA $\rightarrow$ PEPA	D.	Aldolase

[MHCET 2015]

- (a) 1-D, 2-C, 3-B, 4-A (b) 1-A, 2-B, 3-C, 4-D  
 (c) 1-B, 2-A, 3-D, 4-C (d) 1-C, 2-D, 3-A, 4-B
32. In muscles from three molecules of glucose, two are completely oxidized and one is incompletely oxidized (anaerobic) then, what will be the number of total  $NAD^+$  molecules utilized [GUJCET 2014]  
 (a) 10 (b) 20  
 (c) 14 (d) 08
33. Which of the following process occurs in glycolysis [JIPMER 2002]  
 (a) Oxidation (b) Reduction  
 (c) Hydrogenation (d) Fixation

34. The given figure indicates the interrelationship among metabolic pathways. Identify A to D [NCERT]



	A	B	C	D
(a)	Fat	DHAP	Acetyl CoA	Protein
(b)	Acetyl CoA	Fat	DHAP	Protein
(c)	Fat	DHAP	Protein	Acetyl CoA
(d)	Protein	Acetyl CoA	Fat	DHAP

35. Glucose is [MP PMT 2013]  
 (a) Pyranose pentose sugar (b) Furanose pentose sugar  
 (c) Ketose hexose sugar (d) Aldose hexose sugar
36. Which of the following biomolecules is common to respiration-mediated breakdown of fats, carbohydrates and proteins [NEET (Phase-II) 2016]  
 (a) Acetyl CoA  
 (b) Glucose-6-phosphate  
 (c) Fructose 1, 6-bisphosphate  
 (d) Pyruvic acid

### Kreb's cycle and ETS

1. The details of tricarboxylic acid path was worked out by [Odisha JEE 2008; AFMC 2012]  
 (a) Meischer (b) Hans Krebs  
 (c) Pasteur (d) None of these
2. The product formed by malic dehydrogenase is  
 (a) Malic acid (b) Fumanc acid  
 (c) Oxaloacetic acid (d) Succinic acid
3. During Krebs' cycle energy from glucose is mostly transferred to [Odisha JEE 2009]  
 (a) NADH & FADH (b) NADPH  
 (c) ADP (d) Water
4. The number of carbon atom in citric acid is [Odisha JEE 2008]  
 (a) 8 (b) 6  
 (c) 10 (d) 2
5. Hydrogen of malate is accepted by  
 (a) FAD (b) FMN  
 (c) COQ (d) NAD
6. During aerobic respiration maximum ATP is synthesized by [Odisha JEE 2009]  
 (a) ETS (b) Krebs' cycle  
 (c) Glycolysis (d) Fermentation
7. Which one of the following is complex V of the ETS of inner mitochondrial membrane [Kerala PMT 2009]  
 (a) NADH dehydrogenase (b) Cytochrome c oxidase  
 (c) Ubiquinone (d) Succinate dehydrogenase  
 (e) ATP synthase
8. Which intermediate compound is involved in the synthesis of amino acids  
 (a) Malic acid (b) Citric acid  
 (c)  $\alpha$ -ketoglutaric acid (d) Isocitric acid
9. During one Krebs' cycle number of  $\text{CO}_2$  molecules released is [MH CET 2005; AMU (Med.) 2009]  
 (a) 1 (b) 2  
 (c) 3 (d) 4
10. During movement of electron through ETC [BHU 2012]  
 (a) pH of matrix increases  
 (b) Electrons are transported by active transport  
 (c) Electrons are resonated  
 (d) Electrons show fluorescence
11. In citric acid cycle decarboxylation occurs when [AMU (Med.) 2010]  
 (a) Citric acid converts to  $\alpha$ -ketoglutaric acid  
 (b) Succinic acid converts to malic acid  
 (c) Malic acid converts to oxaloacetic acid  
 (d) Oxaloacetic acid converts to citric acid
12. The overall goal of glycolysis, Krebs cycle and the electron transport system is the formation of [CBSE PMT 2007]  
 (a) ATP in small stepwise units  
 (b) ATP in one large oxidation reaction  
 (c) Sugars  
 (d) Nucleic acids
13. In the electron transport system present in the inner mitochondrial membrane, complexes I and IV are respectively [Kerala PMT 2011]  
 (a) NADH dehydrogenase and  $\text{FADH}_2$   
 (b)  $\text{FADH}_2$  and NADH dehydrogenase  
 (c) NADH dehydrogenase and cytochrome oxidase complex  
 (d) NADH dehydrogenase and ATP synthase  
 (e) Cytochrome bc 1 complex and NADH dehydrogenase
14. Krebs' cycle was discovered by Krebs in pigeon muscles in 1940. Which step is called gateway step. Link reaction/transition reaction in respiration [NCERT; AFMC 2006]  
 (a) Glycolysis (b) Formation of acetyl-coA  
 (c) Citric acid formation (d) ETS terminal oxidation
15. In Krebs' cycle formation of [RPMT 2001, 06; Bihar CECE 2006]  
 (a) 34 ATP takes place  
 (b) 38 ATP takes place  
 (c) 15 ATP from each acetyl Co-A takes place  
 (d) 12 ATP from each acetyl Co-A takes place (24 ATP)

16. All enzymes of TCA cycle are located in the mitochondrial matrix except one which is located in inner mitochondrial membranes in eukaryotes and in cytosol in prokaryotes. This enzyme is [AIIMS 1994; CBSE PMT 2007]  
 (a) Lactate dehydrogenase (b) Isocitrate dehydrogenase  
 (c) Malate dehydrogenase (d) Succinate dehydrogenase
17. Cytochrome oxidase is a/an [MP PMT 2007]  
 (a) Exoenzyme (b) Endoenzyme  
 (c) Proenzyme (d) Coenzyme
18. Synthesis of ATP in mitochondria require  
 (a) Oxygen (b) NADP  
 (c) FMN (d) Pyruvic acid
19. Which of these steps in Krebs' cycle indicates substrate level phosphorylation [Kerala PMT 2011]  
 (a) Conversion of succinic acid to  $\alpha$ -ketoglutaric acid  
 (b) Conversion of succinic acid to malic acid  
 (c) Conversion of succinyl Co. A to succinic acid  
 (d) Conversion of malic acid to oxalo acetic acid  
 (e) Conversion of citric acid to  $\alpha$ -ketoglutaric acid
20. Most of the energy in the cell is liberated by oxidation of carbohydrate when  
 (a) Pyruvic acid is converted into  $\text{CO}_2$  and  $\text{H}_2\text{O}$   
 (b) Pyruvic acid is converted into Acetyl CoA  
 (c) Sugar is converted into pyruvic acid  
 (d) Glucose is converted in alcohol and  $\text{CO}_2$
21. Complete oxidation of 1 gm molecule of glucose gives rise to [RPMT 1997]  
 (a) 68,60,000 cal (b) 6,86,000 cal  
 (c) 68,600 cal (d) 6,800 cal
22. Pyruvic acid is converted into a compound before formation of oxaloacetic acid in the citric acid cycle, this compound is [MP PMT 2002]

Or

Which of the following metabolites enter the TCA cycle during glucose oxidation [WB JEE 2016]

- (a) Acetyl CoA (b) Acetoacetic acid  
 (c) Lactic acid (d) cis aconitic acid
23. In respiration, pyruvic acid is  
 (a) Formed only when oxygen is available  
 (b) One of the product of Krebs' cycle  
 (c) Broken down into two carbon fragments and  $\text{CO}_2$   
 (d) A result of protein breakdown
24. Match the number of carbon atoms given in List - I with that of the compounds given in List - II and select the correct option

	List - I		List - II
A.	4C Compound	1.	Acetyl CoA
B.	2C Compound	2.	Pyruvate
C.	5C Compound	3.	Citric acid
D.	3C Compound	4.	$\alpha$ -keto glutaric acid
		5.	Malic acid

[NCERT; Kerala PMT 2007, 08]

- (a) A-2, B-5, C-3, D-1 (b) A-5, B-1, C-4, D-2  
 (c) A-3, B-1, C-4, D-2 (d) A-5, B-3, C-1, D-2  
 (e) A-3, B-4, C-1, D-5
25. In Krebs' cycle OAA accepts acetyl CoA to form [Odisha JEE 2010]  
 (a) Citric acid (b) Oxalosuccinate  
 (c) Fumarate (d) Succinyl CoA

26. The reaction of Krebs' cycle (TCA cycle) take place [CPMT 1994; CBSE PMT 1996; MP PMT 1997; BVP 2001; JIPMER 2001; MHCET 2002; AIEEE Pharmacy 2003; Odisha JEE 2005, 10, 12; KCET 2012]

Or

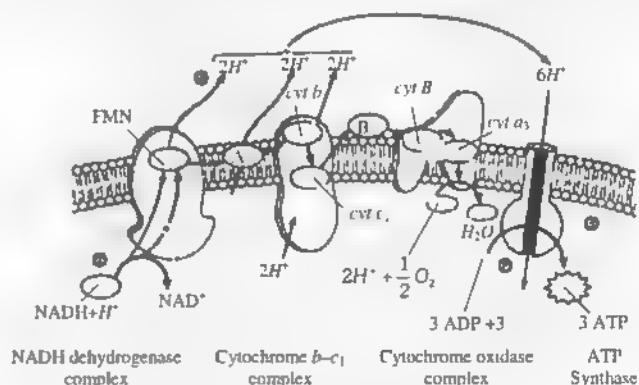
Pyruvate dehydrogenase complex, needed for the conversion of pyruvic acid to acetyl CoA is located in ..... [KCET 2010]

- (a) In cytoplasm  
 (b) In endoplasmic reticulum  
 (c) In matrix of mitochondria  
 (d) On the surface of mitochondrion
27. Which one is not correct about Krebs' cycle [KCET 2007]  
 (a) It is also called citric acid cycle  
 (b) The intermediate compound which links glycolysis with Krebs' cycle is malic acid  
 (c) It occurs in mitochondria  
 (d) It starts with six carbon compound
28. During which stage in the complete oxidation of glucose are the greatest number of ATP molecules formed from ADP [CBSE PMT 2005]

Or

Largest amount of phosphate bond energy is produced in the process of respiration during [BHU 2002]

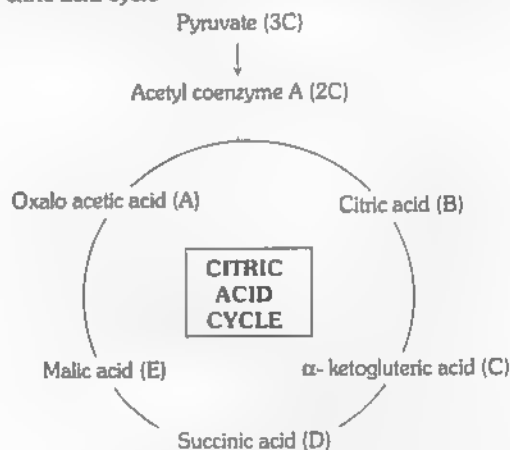
- (a) Conversion pyruvic acid to acetyl CoA  
 (b) Electron transport chain  
 (c) Glycolysis  
 (d) Krebs' cycle
29. Choose the correct statement [KCET 2015]  
 (a) Oxygen is vital in respiration for removal of Hydrogen  
 (b) Pyruvate is formed in the mitochondrial matrix  
 (c) There is complete breakdown of glucose in fermentation  
 (d) During the conversion of Succinyl CoA to Succinic acid a molecule of ATP is synthesized
30. In Krebs' cycle the hydrogen atoms removed at succinate level are accepted by  
 (a) FAD (b) ADP  
 (c) ATP (d) NAD
31. The following is a scheme showing the electron transport system. Identify the electron carrier molecules indicated as A and B. Choose the correct option [KCET 2010]



- (a) A = coenzyme Q, B = cytochrome c  
 (b) A = cytochrome c, B = coenzyme Q  
 (c) A = Fe-S protein, B = FMN  
 (d) A = FMN, B = Fe-S protein

32. Oxidative phosphorylation occurs in  
[RPMT 1995; Pune CET 1998; JIPMER 2001]  
(a) Outer membrane of mitochondria  
(b) Inner membrane of mitochondria  
(c) Stroma of chloroplast  
(d) Grana of chloroplast
33. The enzymes for electron transport system are located in the  
[Kerala PMT 2004]  
Or  
Cellular energy is provided through respiration and oxidation by  
(a) Plastid (b) Endoplasmic reticulum  
(c) Ribosomes (d) Mitochondria  
(e) Golgi bodies
34. Respiratory enzymes are located in  
[RPMT 1995; Bihar MDAT 1995; MP PMT 2001; AFMC 2003; AMU (Med.) 2005; BHU 2008; WB JEE 2009; Odisha JEE 2011]  
(a) Mitochondrial matrix (mitochondria)  
(b) Perimitochondrial space  
(c) Cristae  
(d) Outer membrane
35. Food is converted to energy in  
(a) Chloroplast (b) Nucleus  
(c) Mitochondria (d) None of the above
36. ATP molecules produced respectively by  $\text{NADH}(\text{H}^+)$  and  $\text{FADH}_2$  during electron transport are [MP PMT 2013]  
(a) 3 and 2 (b) 1 and 1  
(c) 2 and 3 (d) 3 and 3
37. Which of the following is correct sequence in Krebs's cycle  
(a) Isocitric acid  $\rightarrow$  Oxalosuccinic acid  $\rightarrow$   $\alpha$ -ketoglutaric acid  
(b) Oxalosuccinic acid  $\rightarrow$  Isocitric acid  $\rightarrow$   $\alpha$ -ketoglutaric acid  
(c)  $\alpha$ -ketoglutaric acid  $\rightarrow$  Isocitric acid  $\rightarrow$  Oxalosuccinic acid  
(d) Isocitric acid  $\rightarrow$   $\alpha$ -ketoglutaric acid  $\rightarrow$  Oxalosuccinic acid
38. In how many steps,  $\text{CO}_2$  is released in aerobic respiration of pyruvic acid  
(a) One (b) Six  
(c) Three (d) Twelve
39. Activity of succinic dehydrogenase involves the following in TCA cycle [DPMT 2004]  
(a) NAD (b) FAD  
(c) GDP (d) ATP
40. The formation of acetyl coenzyme-A from pyruvic acid is the result of its [Kerala PMT 2004; AFMC 2009; KCET 2011]  
(a) Reduction  
(b) Dehydration  
(c) Dephosphorylation  
(d) Oxidative decarboxylation
41. Oxidation of succinate to fumarate in the Krebs's cycle is due to  
(a) Loss of electron from it  
(b) Removal of hydrogen from it  
(c) Addition of oxygen to it  
(d) None of the above
42. Oxidative phosphorylation and photophosphorylation both require the electron carrier  
(a) Cytochrome (b) Oxygen  
(c) Carbon dioxide (d) Water
43. Cytochrome helps in [AFMC 1994; MP PMT 1996]  
(a) Oxidation of glucose (b) Release of energy  
(c) Electron transport (d) Growth
44. In oxidative photophosphorylation, the last 3 steps are as follows [Odisha JEE 2004]  
 $Q \rightarrow C \rightarrow aa_3 \rightarrow O_2$   
(a)  $Q \rightarrow C$  is  $H^+$  absorbing site  
(b)  $aa_3 \rightarrow O_2, H^+$  yielding site  
(c)  $Q \rightarrow C$  is  $H^+$  yielding site and  $aa_3 \rightarrow O_2$  is  $H^+$  absorbing site  
(d) No  $H^+$  is absorbed or released
45. In which one of the following do the two names refer to one and the same thing [CBSE PMT 2003]  
(a) Tricarboxylic acid cycle and urea cycle  
(b) Krebs's cycle and Calvin cycle  
(c) Tricarboxylic acid cycle and citric acid cycle  
(d) Citric acid cycle and Calvin cycle
46. By the reaction of  $\alpha$ -ketoglutaric acid with ammonia, through which of the process glutamic acid is formed [GUJCET 2007]  
(a) Oxidative amination (b) Reductive amination  
(c) Ammonification (d) Transamination
47. Biological oxidation in Krebs's cycle involves [MP PMT 1994; Odisha JEE 2011]  
(a)  $N_2$  (b)  $\text{CO}_2$   
(c)  $O_2$  (d)  $\text{SO}_2$
48. Oxidative phosphorylation is the formation of [CBSE PMT 1992, 96; BHU 1994, 99; Odisha JEE 2009]  
(a)  $\text{NADPH}_2$  in respiration  
(b) ATP in respiration  
(c)  $\text{NADPH}_2$  in photosynthesis  
(d) ATP in photosynthesis
49. Mineral activator needed for the enzyme carboxylase of TCA cycle is  
(a)  $\text{Mg}^{++}$  (b)  $\text{Fe}^{+++}$   
(c)  $\text{Mo}^{++}$  (d)  $\text{Mn}^{++}$
50. Krebs's cycle involves the formation of  
(a) Lactic acid from glucose  
(b) Change of pyruvic acid to energy transformation  
(c) Pyruvic acid from glucose  
(d) ATP from ADP
51. In the electron transport system, the reduced coenzymes are regenerated by  
(a) Loss of hydrogen (b) Loss of electron  
(c) Addition of oxygen (d) None of the above

52. Which of the following does not function as an electron carrier [Kerala PMT 2004]  
 (a) Coenzyme Q (b) Cytochrome-c  
 (c) Cytochrome-a (d) Cytochrome-a<sub>3</sub>  
 (e) H<sub>2</sub>O
53. Kreb's cycle begins with [CBSE PMT 1991]  
 (a) Pyruvic acid (b) Hydrochloric acid  
 (c) Corticosteroids (d) Lysine
54. In ETS, electron combines to [CPMT 1994]  
 (a) Cytochrome (b) H<sub>2</sub>  
 (c) O<sub>2</sub> (d) H<sub>2</sub>O
55. How many ATP molecules could maximally be generated from one molecule of glucose, if the complete oxidation of one mole of glucose to CO<sub>2</sub> and H<sub>2</sub>O yields 686 kcal and the useful chemical energy available in the high energy phosphate bond of one mole of ATP is 12 kcal [CBSE PMT 2006]  
 (a) Fifty-seven (b) One  
 (c) Two (d) Thirty
56. Each molecule of pyruvic acid entering the Kreb's cycle produces  
 (a) 2 molecules of CO<sub>2</sub> (b) 3 molecules of CO<sub>2</sub>  
 (c) 1 molecules of CO<sub>2</sub> (d) 5 molecules of CO<sub>2</sub>
57. The last or terminal cytochrome in respiratory chain is [CBSE PMT 1992; RPMT 1997]  
 Or  
 In an electron transport chain in terminal oxidation the cytochrome which donates electrons to O<sub>2</sub> is  
 (a) Cyt b (b) Cyt a<sub>3</sub>  
 (c) Cyt a (d) Cyt c
58. Upon the oxidation of one mole of pyruvate by mitochondrial respiration, the moles of ATP generated are [BHU 1994; KCET 1998]  
 (a) 38 (b) 30  
 (c) 8 (d) 15
59. Kreb's cycle is also called [EAMCET 1995; MHCET 2003; WB JEE 2009]  
 (a) TCA cycle (b) Citric acid cycle  
 (c) Tricarboxylic cycle (d) All the above
60. Kreb's cycle is found in [AFMC 1996]  
 (a) Anaerobic respiration (b) Photorespiration  
 (c) Photosynthesis (d) Aerobic respiration
61. The importance of Kreb's cycle is in the production of [MP PMT 1996]  
 (a) Acetyl CoA (b) Water  
 (c) ATP (d) ADP
62. The correct sequence of electron acceptor in ATP synthesis is [CBSE PMT 1997; MHCET 2002, 06]  
 (a) Cyt a a b c (b) Cyt b c a a<sub>3</sub>  
 (c) Cyt b c a<sub>3</sub> a (d) Cyt c b a a<sub>3</sub>
63. In Kreb's cycle, the FAD participates as electron acceptor during the conversion of [CBSE PMT 1997; MHCET 2002; AMU (Med.) 2009; WB JEE 2009; AFMC 2010]  
 (a) Succinyl CoA to succinic acid  
 (b) α-ketoglutarate to succinyl CoA  
 (c) Fumaric acid to malic acid  
 (d) Succinic acid to fumaric acid
64. Which transfer electrons in E.T.S. (Electron Transport System) [CPMT 1998]  
 (a) Phytochrome (b) F<sub>1</sub> particles  
 (c) Fe - S (d) None of these
65. The pyruvic acid formed in Glycolysis is oxidised to CO<sub>2</sub> and H<sub>2</sub>O in a cycle called [NCERT; MP PMT 1999; J & K CET 2008]  
 (a) Calvin cycle (b) Hill reaction  
 (c) Kreb's cycle (d) Nitrogen cycle
66. Which one of the following energy storing compound is formed when succinyl CoA is converted into succinic acid [BHU 2000]  
 (a) ADP (b) ATP  
 (c) AMP (d) GTP
67. Which of the following is not an electron transferring molecule [KCET 2001]  
 (a) ATP (b) NAD<sup>+</sup>  
 (c) Fe-S protein (d) Co-enzyme Q
68. Cytochromes are [CBSE PMT 2001]  
 (a) Lipid  
 (b) Glycoprotein  
 (c) Metalloporphyrins  
 (d) Fe<sup>++</sup> containing with porphyrin pigment
69. Cytochromes occur in [BHU 2001; AIPMT (Cancelled) 2015]  
 (a) Cristae of mitochondria  
 (b) Matrix of mitochondria  
 (c) Outer mitochondrial membrane  
 (d) Entire inner mitochondrial membrane
70. Final electron acceptor in ETS is [Kerala CET 2002; CPMT 2003; BHU 2004; RPMT 2006; Odisha JEE 2009; MH CET 2015]  
 (a) H<sub>2</sub>O (b) O<sub>2</sub>  
 (c) Cyt a<sub>3</sub> (d) Cyt a
71. Choose the correct combination of labelling the number of carbon compounds in the substrate molecules, involved in the citric acid cycle



- [NCERT; Kerala PMT 2006]  
 (a) (A) 4C, (B) 6C, (C) 5C, (D) 4C, (E) 4C  
 (b) (A) 6C, (B) 5C, (C) 4C, (D) 3C, (E) 2C  
 (c) (A) 2C, (B) 5C, (C) 6C, (D) 4C, (E) 4C  
 (d) (A) 4C, (B) 6C, (C) 4C, (D) 4C, (E) 5C  
 (e) (A) 4C, (B) 6C, (C) 4C, (D) 4C, (E) 4C



72. Oxidative phosphorylation is [NEET (Phase-II) 2016]  
 (a) Formation of ATP energy released from electrons removed during substrate oxidation  
 (b) Formation of ATP by transfer of phosphate group from a substrate to ADP  
 (c) Oxidation of phosphate group in ATP  
 (d) Addition of phosphate group to ATP
73. Which statement is wrong for Krebs' cycle [NEET 2017]  
 (a) There are three points in the cycle where  $\text{NAD}^+$  is reduced to  $\text{NADH} + \text{H}^+$   
 (b) There is one point in the cycle where  $\text{FAD}^+$  is reduced to  $\text{FADH}_2$   
 (c) During conversion of succinyl CoA to succinic acid, a molecule of GTP is synthesised  
 (d) The cycle starts with condensation of acetyl group (acetyl CoA) with pyruvic acid yield citric acid
8. HMP shunt is a set of reactions  
 (a) Called pentose phosphate pathway  
 (b) Which bypasses EMP route of glucose oxidation  
 (c) Either of the above  
 (d) Which converts glucose to phosphoglycerate
9. Pentose phosphate pathway, an alternative pathway of respiration was elucidated by  
 (a) Horecker (b) Warburg and Dickens  
 (c) Blackman (d) Kelvin
10. In hexose monophosphate shunt, the number of  $\text{CO}_2$  molecules evolved is  
 (a) Same as in glycolysis  
 (b) Less than glycolysis  
 (c) More than glycolysis  
 (d) Much lesser than glycolysis
11. Which of the following is produced in oxidative pentose phosphate pathway [Kerala PMT 2007]  
 (a) Pyruvic acid (b) Acetyl CoA  
 (c)  $\text{NADH}_2$  (d)  $\text{NAD(P)H}$   
 (e) ATP

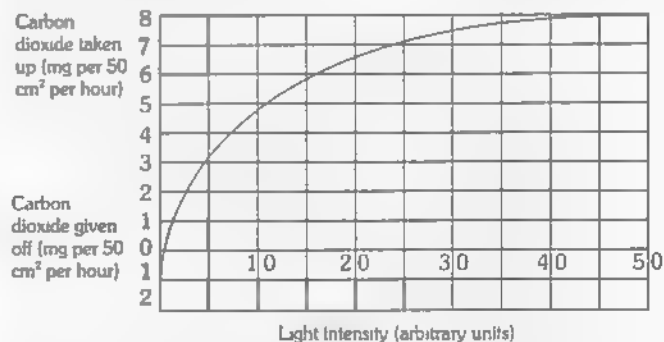
### Pentose phosphate pathway

1. The reactions of pentose phosphate pathway (PPP) take place in [Kerala PMT 2009]  
 (a) Mitochondrion  
 (b) Cytoplasm  
 (c) Chloroplast, peroxisome and mitochondrion  
 (d) Chloroplast, glyoxysome and mitochondrion  
 (e) Chloroplast, lysosome and mitochondrion
2. Which of the following is a direct oxidation pathway being performed without glycolysis  
 (a) TCA cycle (b) HMP pathway  
 (c) Both (a) and (b) (d) None of the above
3. In which of the following process 36 ATP molecules are produced by per hexose molecule  
 (a) Glycolysis (b) Kreb's cycle  
 (c) Direct oxidation pathway (d) None of the above
4. The substrate for pentose phosphate pathway is [BHU 2012]  
 (a) Glucose-6-phosphate (b) Glucose-1-phosphate  
 (c) Fructose-6-phosphate (d) Fructose-1-phosphate
5. Shikimic acid can be made from  
 (a) Xylulose (b) Erythrose-4-phosphate  
 (c) Ribulose (d) None of the above
6. HMP shunt is an alternative to  
 (a) Kreb's cycle (b) Aerobic glycolysis  
 (c) Calvin cycle (d)  $\text{C}_4$  pathway
7. Which of the following statements is / are not true  
 A. One ATP molecule yields 32 kJ of energy  
 B. Pentose Phosphate Pathway was discovered by Dickens  
 C. When tripalmitin is used as a substrate, the R.Q. is 0.7  
 D. Energy released by one molecule of glucose on complete oxidation corresponds to 1292 kJ [Kerala PMT 2006]  
 (a) A, B and D only (b) C and D only  
 (c) A and D only (d) A, C and D only  
 (e) C only
8. R.Q. for glucose (Carbohydrates) is [AFMC 1993; CPMT 1998; Bihar CECE 2005; J & K CET 2008]  
 (a) 1 (b) 0.5  
 (c) 2 (d) 0.05
2. If R. Q. is less than 1.0 in a respiratory metabolism, it would mean that [Kerala PMT 2008]  
 (a) Carbohydrates are used as respiratory substrate  
 (b) Organic acids are used as respiratory substrate  
 (c) The oxidation of the respiratory substrate consumed more oxygen than the amount of  $\text{CO}_2$  released  
 (d) The oxidation of the respiratory substrate consumed less oxygen than the amount of  $\text{CO}_2$  released  
 (e) The reaction is anaerobic
3. Which of the following respiratory material may show the unit value of R.Q.  
 (a) Stem of wheat (b) Leaf of barley  
 (c) Leaf of oat (d) All the above
4. Which of the following respiratory substrates requires the highest number of  $\text{O}_2$  molecules for its complete oxidation [IEMCET 2009]  
 (a) Tripalmitin (b) Triolein  
 (c) Tartaric acid (d) Oleic acid
5. Substance whose RQ is less than one is [CPMT 1994]  
 (a) Carbohydrate (b) Protein  
 (c) Organic acid (d) All the above
6. When the respiratory substances are more than one then which respiratory substrates are not used [GUJCET 2015]  
 (a) Pure Protein (b) Lipid  
 (c) Carbohydrate (d) (A) and (B) both
7. What is the value of RQ of castor seeds, if the imaginary values of Ganong's respirometer are as follows  
 (i) First rise of saline = 10 ml  
 (ii) Second rise of saline after adding KOH = 30 ml  
 (a) 0.33 (b) 0.75  
 (c) 0.85 (d) 3.00

8. The energy content in Kcal/g of carbohydrate : protein : triglycerol respectively is approximately in the ratio of [AMU (Med.) 2010, 12]  
(a) 1:2:2 (b) 1:1:2  
(c) 2:1:1 (d) 2:2:1
9. The respiratory quotient during cellular respiration would depend on [KCET 2009]  
(a) The nature of enzymes involved  
(b) The nature of the substrate  
(c) The amount of carbon dioxide released  
(d) The amount of oxygen utilised
10. R.Q. in anaerobic respiration is [JIPMER 1998; Wardha 2005]  
(a) 0 (b)  $\infty$   
(c) 1 (d)  $> 1$
11. The R.Q. of a plant organ depends upon the nature of the substrate which is  
(a) Reduced (b) Oxidized  
(c) Catabolized (d) Metabolized
12. R.Q. of fatty substances is generally [RPMT 1999, 2002; KCET 1999; AMU (Med.) 2012]  
(a) Unity (b) Less than one (Approx 0.7)  
(c) Greater than one (d) Zero
13. Which of the following option is correct for the given statements, 'X', 'Y' and 'Z'  
Statement 'X' – R.Q. of fat containing palmitic acid is less than one, whereas R.Q. of glucose is 1  
Statement 'Y' – Fat containing palmitic acid need less  $O_2$  for respiration and glucose need more oxygen for respiration  
Statement 'Z' – Fat containing palmitic acid has much less oxygen in its constitution as compared to glucose [GUJCET 2014]  
(a) Statement 'X', 'Y' and 'Z' are correct. Statement 'Y' and 'Z' are correct explanation for 'X'  
(b) Statement 'X' and 'Y' are correct and statement 'Z' is incorrect statement, 'Y' is correct explanation for 'X'  
(c) Statement 'X' and 'Z' are correct and statement 'Y' is incorrect statement, 'Z' is correct explanation for 'X'  
(d) Statement 'X' and 'Z' are incorrect and statement 'Y' is correct
14. In *Opuntia*, in night the R.Q. will be  
(a) One (b) Less than one  
(c) More than one (d) Zero
15. In succulents respiratory quotient is always less than one because of  
(a) Complete oxidation (b) Complete reduction  
(c) Incomplete oxidation (d) Incomplete reduction
16. The R.Q. value of oxalic acid is [Kerala PMT 2009]  
(a) 1.0 (b) 0.7  
(c) 4 (d)  $\infty$   
(e) 1.5
17. In germinating castor seeds, the R.Q. is [BHU 1995, 2003; CBSE PMT 2002; MHCET 2003; MP PMT 2011]  
Or  
A mixture containing equal quantity of germinating maize and groundnut seeds are taken. The RQ of this mixture would be  
(a) One (b) More than one  
(c) Less than one (d) Zero
18. R.Q. of malic acid is [RPMT 1995]  
(a) 0.7 (b) 1  
(c) 1.33 (d) 4
19. The correct relationship of value of Respiratory Quotient is [RPMT 1997]  
(a) Glucose symbol  $>$  Fats symbol  $>$  Organic acid  
(b) Glucose symbol  $<$  Fats symbol  $<$  Organic acid  
(c) Fats symbol  $>$  Glucose symbol  $>$  Organic acid  
(d) Fats symbol  $<$  Glucose symbol  $<$  Organic acid
20. R.Q. is more than one in case of [MP PMT 2000]  
Or  
If the volume of  $CO_2$  liberated during respiration is more than the volume of  $O_2$  used, the respiratory substance will be  
(a) Fat (b) Fructose  
(c) Glucose (d) Organic acid
21. R.Q. of sprouting potato tubers will be [BVP 2002]  
(a) 1 (b)  $< 1$   
(c)  $> 1$  (d) 0
22. RQ (respiratory quotient) is defined as [NCERT; DPMT 2003, 04; KCET 2004; BVP 2004; Kerala PMT 2006]  
(a) Volume of  $CO_2$  evolved = volume of  $O_2$  consumed  
(b)  $\frac{\text{Volume of } O_2 \text{ consumed}}{\text{Volume of } CO_2 \text{ evolved}}$   
(c)  $\frac{\text{Volume of } CO_2 \text{ evolved}}{\text{Volume of } O_2 \text{ consumed}}$   
(d)  $\frac{\text{Volume of } O_2 \text{ evolved}}{\text{Volume of } CO_2 \text{ consumed}}$

### Factor affecting respiration

1. The graph shows the relation between light intensity and the giving off and taking up of carbon dioxide by the leaves of a plant. Why is most carbon dioxide given off when the light intensity is zero units



[Kerala PMT 2004]

- (a) Because it is just the start of the experiment  
(b) Only respiration is taking place at this intensity of light  
(c) Only photosynthesis is taking place at this intensity of light  
(d) The rate of photosynthesis is equivalent to the rate of respiration  
(e) The rate of photosynthesis is more than the rate of respiration

2. The potato growing in hilly areas is bigger in size due to  
 (a) High rate of photosynthesis at high altitude  
 (b) Low rate of respiration at high altitude  
 (c) Due to formation of more fat  
 (d) None of the above
3. When an unripe banana is sealed in a polythene bag, it remains green for many days. But if an apple is also sealed in the same bag, the banana ripens and turns yellow within a few days. The reason is that apple [BHU 1994]  
 (a) Removes  $O_2$  released by the banana and thus promotes ripening  
 (b) Produces  $CO_2$  which promotes ripening  
 (c) Removes  $CO_2$  which inhibits ripening  
 (d) Releases ethylene which promotes ripening
4. If the temperature is increased (above  $35^\circ C$ )  
 (a) Rate of decline of respiration will be earlier than decline of photosynthesis  
 (b) Rate of decline of photosynthesis will be earlier than decline of respiration  
 (c) Both decline simultaneously  
 (d) Both do not show any fixed pattern
5.  $CO_2$  concentration has which relation with respiration  
 (a) Directly proportional (b) Inversely proportional  
 (c) Both (a) and (b) (d) No relation
6. Which statement is wrong  
 (a) Stomatal opening is influenced by many factors and potassium  
 (b) All enzymes are proteins but all proteins are not enzymes  
 (c) All angiosperms are with seeds but all seed plants are not angiosperms  
 (d) Factors which effect the respiration influence the photosynthesis but reverse is not possible
7. Which of the following is necessary for respiration in plants  
 (a) Carbon dioxide (b) Oxygen  
 (c) Chlorophyll (d) Light
8. The rate of respiration of young maturing seeds is quite high but as water contents decreases during further maturation, respiration  
 (a) Remains high (b) Stops completely  
 (c) Increases steadily (d) Decreases steadily
9. In presence of cyanide, azide and carbon monoxide, the rate of respiration  
 (a) Decreases (b) Increases  
 (c) Remains the same (d) None of the above
3. Pyruvic acid, the key product of glycolysis can have many metabolic fates. Under aerobic condition it forms [NCERT]  
 (a) Lactic acid (b)  $CO_2 + H_2O$   
 (c) Acetyl Co A +  $CO_2$  (d) Ethanol +  $CO_2$
4. Electron Transport System (ETS) is located in mitochondrial [NCERT]  
 (a) Outer membrane (b) Inter membrane space  
 (c) Inner membrane (d) Matrix
5. Match the following and choose the correct option from those given below
- | Column A                  | Column B                        |
|---------------------------|---------------------------------|
| A. Molecular oxygen       | i. $\alpha$ - Ketoglutaric acid |
| B. Electron acceptor      | ii. hydrogen acceptor           |
| C. Pyruvate dehydrogenase | iii. Cytochrome C               |
| D. Decarboxylation        | iv. acetyl Co A                 |
- Options [NCERT]  
 (a) A-ii, B-iii, C-iv, D-i  
 (b) A-iii, B-iv, C-ii, D-i  
 (c) A-ii, B-i, C-iii, D-iv  
 (d) A-iv, B-iii, C-i, D-ii
6. Choose the correct statement [NCERT]  
 (a) Pyruvate is formed in the mitochondrial matrix  
 (b) During the conversion of succinyl Co-A to succinic acid a molecule of ATP is synthesized  
 (c) Oxygen is vital in respiration for removal of hydrogen  
 (d) There is complete breakdown of glucose in fermentation
7. Mitochondria are called power houses of the cell. Which of the following observations support this statement [NCERT]  
 (a) Mitochondria synthesise ATP  
 (b) Mitochondria have a double membrane  
 (c) The enzymes of the Krebs cycle and the cytochromes are found in mitochondria  
 (d) Mitochondria are found in almost all plants and animal cells
8. The end product of oxidative phosphorylation is [NCERT]  
 (a) NADH (b) Oxygen  
 (c) ADP (d)  $ATP + H_2O$

# NQ NCERT

## Exemplar Questions

1. The ultimate electron acceptor of respiration in an aerobic organisms is [NCERT]  
 (a) Cytochrome (b) Oxygen  
 (c) Hydrogen (d) Glucose
2. Phosphorylation of glucose during glycolysis is catalysed by [NCERT]  
 (a) Phosphoglucumutase (b) Phosphoglucoisomerase  
 (c) Hexokinase (d) Phosphorylase

# GT Critical Thinking

## Objective Questions

1. The chemiosmotic coupling hypothesis of oxidative phosphorylation proposes that adenosine triphosphate (ATP) is formed because [CBSE PMT 2008; DUMET 2009]  
 (a) A proton gradient forms across the inner membrane  
 (b) There is a change in the permeability of the inner mitochondrial membrane toward adenosine diphosphate (ADP)  
 (c) High energy bonds are formed in mitochondrial proteins  
 (d) ADP is pumped out of the matrix into the intermembrane space

2. How many molecules of ATP and NADPH are require in formation of two molecules of glucose? How many calvin cycles are required [GUJCET 2015]

(a) 36 ATP, 24 NADPH, 12 Calvin cycles  
(b) 18 ATP, 12 NADPH, 6 Calvin cycles  
(c) 36 ATP, 24 NADPH, 6 Calvin cycles  
(d) 24 ATP, 36 NADPH, 12 Calvin cycles

3. Four respiratory enzymes are given below. Arrange them in increasing order of the carbon number of the substrates on which they act

(I) Enolase (II) Aconitase  
(III) Fumerase (IV) Alcohol dehydrogenase

[EAMCET 2009]

(a) II, IV, III, I (b) IV, I, II, III  
(c) I, IV, III, II (d) IV, I, III, II

4. Match the compounds given in Column I with the number of carbon atoms present in them which are listed under Column II. Choose the answer which given the correct combination of alphabets of the two columns

Column-I		Column-II	
(A)	Oxaloacetate	(p)	6-C compound
(B)	Phosphoglycrealdehyde	(q)	5-C compound
(C)	Isocitrate	(r)	4-C compound
(D)	$\alpha$ -ketoglutarate	(s)	3-C compound
		(t)	2-C compound

[KCET 2009]

A	B	C	D
(a) s	t	q	r
(b) r	s	p	q
(c) r	t	p	q
(d) q	s	p	t

5. In respiration the energy is produced during the process of  
(a) Glycolysis (b) Krebs cycle  
(c) Glycolysis and Kreb's cycle (d) Ornithine cycle
6. Hibernating animals have tissues containing mitochondria with a membrane protein that accelerates electron transport while blocking the synthesis of ATP. What is the consequence of this [KCET 2015]  
(a) Hibernating animals can synthesize fat instead of wasting energy of respiration  
(b) Energy is saved because glycolysis and the citric acid cycle shuts down  
(c) Pyruvate is converted to lactic acid by anaerobic fermentation  
(d) The energy of respiration is converted into heat
7. Production of glucose from amino acids, fatty acids and glycerol is called [MP PMT 2009]

Or

Synthesis of glucose from sources other than Carbohydrate is called [WB JEE 2016]

(a) Glycogenesis (b) Gluconeogenesis  
(c) Glycogenolysis (d) Glycolysis

8. Net yield of aerobic respiration during Krebs' cycle per glucose molecule is [WB JEE 2009]

(a) 2 ATP molecules (b) 8 ATP molecules  
(c) 36 ATP molecules (d) 38 ATP molecules

9. Which of the following is non-enzymatic phosphorylation

(a) Formation of fructose 1, 6-diphosphate  
(b) Formation of dihydroxyacetone phosphate  
(c) Formation of 1, 3-diphosphoglyceraldehyde  
(d) All the above

10. In alcohol fermentation [CBSE PMT 2003]

(a) Oxygen is the electron acceptor  
(b) Triose phosphate is the electron donor while acetaldehyde is the electron acceptor  
(c) Triose phosphate is the electron donor while pyruvic acid is the electron acceptor  
(d) There is no electron donor

11. The number of glucose molecules required to produce 38 ATP molecules under anaerobic conditions by a yeast cells is

[Kerala PMT 2004; AFMC 2009]

(a) 2 (b) 4  
(c) 19 (d) 25  
(e) 38

12. Harden and Young's ester is formed during glycolysis from

(a) Fructose-6-phosphate (b) Glucose-6-phosphate  
(c) Glucose (d) None of the above

13. Select the wrong statement [Kerala PMT 2010, 11]

(a) When tripalmitin is used as a substrate in respiration, the R.Q. is 0.7  
(b) The intermediate compound which links glycolysis with Kreb's cycle is malic acid  
(c) One glucose molecule yields a net gain of 36 ATP molecules during aerobic respiration  
(d) One glucose molecule yields a net gain of 2 ATP molecules during fermentation  
(e) The scheme of glycolysis was given by Embden, Meyerhof and Parnas

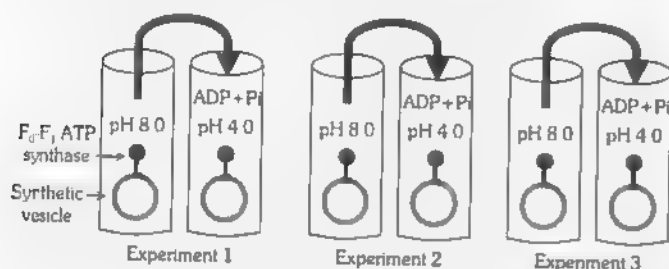
14. Which among the following is the most appropriate reason for storing green coloured apples at low temperature (Refrigerator)

(a) The rate of photosynthesis is reduced  
(b) Respiration and photosynthesis are completely inhibited  
(c) The rate of respiration is reduced  
(d) The rate of photosynthesis and respiration are reduced

15. In the process of respiration in plants 180 gms of sugar plus 192 gms of oxygen produce

(a) Large amount of  $\text{CO}_2$ , no water and no energy  
(b) 132 gms of  $\text{CO}_2$ , 54 gms of water and 337 kJ of energy  
(c) 264 gms of  $\text{CO}_2$ , 108 gms of water and 674 kJ of energy  
(d) 528 gms of  $\text{CO}_2$ , 216 gms of water and 1348 kJ of energy

16. When ATP molecule is hydrolysed in ADP, then the quantity of energy released is about  
 (a) 120 cal (b) 1, 200 cal  
 (c) 12,000 cal (d) 1,20,000 cal
17. The R.Q. (Respiratory quotient) of  $C_{39}H_{72}O_6$  is  
 (a) 2.71 (b) 1.34  
 (c) 0.72 (d) 3.250
18. Experiments 1, 2 and 3 were conducted wherein synthetic vesicles containing  $F_0 - F_1$  ATP synthase were prepared and incubated overnight in a tube. Subsequently, the vesicles were transferred to another tube which also contained ADP and Pi (inorganic phosphate)



- A. A proton gradient across the vesicular membrane will be present in both experiments 1 and 2 at the time of transfer
- B. As a consequence of the proton gradient, ATP will be synthesized in both experiments 1 and 2
- C. ATP will be synthesized in experiment 3 because  $F_0 - F_1$  ATP synthase has the inherent property to catalyse the synthesis of ATP from ADP and Pi
- D. ATP will be synthesized in experiment 2 because the proton has to flow out of the vesicles through the  $F_0 - F_1$  ATP synthase for ATP synthesis [NCERT]
- (a) A and D (b) C and D  
 (c) B and C (d) A and B
19. The time taken from the fixation of  $CO_2$  to the formation of one glucose molecules is about \_\_\_\_\_ seconds [MHCET 2015]  
 (a) 20 (b) 40  
 (c) 60 (d) 90
20. In an experiment demonstrating the evolution of oxygen in *Hydrilla*, sodium bicarbonate is added to water in the experimental set-up. What would happen if all other conditions are favourable [KCET 2009]  
 (a) Amount of oxygen evolved decreases as carbon dioxide in water is absorbed by sodium bicarbonate  
 (b) Amount of oxygen evolved increases as the availability of carbon dioxide increases  
 (c) Amount of oxygen evolved decreases as the availability of carbon dioxide increases  
 (d) Amount of oxygen evolved increases as carbon dioxide in water is absorbed by sodium bicarbonate

## Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

- (a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion  
 (b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion  
 (c) If the assertion is true but the reason is false  
 (d) If both the assertion and reason are false  
 (e) If the assertion is false but reason is true

1. Assertion : In alcoholic fermentation, the hexose molecule is converted into glucose and fructose.  
 Reason : Alcoholic fermentation is anaerobic respiration brought about by enzyme zymase. [AIIMS 1996]
2. Assertion : Glycolysis occurs in cytoplasm.  
 Reason : Enzymes for glycolysis are found in cytoplasm. It is common in aerobic/anaerobic respiration. [AIIMS 2002]
3. Assertion : In electron transport chain, there is a gain of energy at each step.  
 Reason : At each step of ETC, there are electron carriers.
4. Assertion : The inner membrane of mitochondria contains systems involving electron transport.  
 Reason : The mitochondrial matrix contains enzymes of Krebs cycle.
5. Assertion : Both hexokinase and glucokinase require divalent cation  $Mg^{++}$  or  $Mn^{++}$ .  
 Reason : The divalent cations act as catalysts.
6. Assertion : One way of indicating the ATP yield from oxidative phosphorylation is the P/O ratio.  
 Reason : The cell stores 40% of the chemical energy.
7. Assertion : Cytochromes are a group of copper containing electron transferring proteins.  
 Reason : The terminal cytochrome reacts with oxygen.
8. Assertion : Cytochrome oxidase enzyme contains copper  
 Reason : Cyanide combines with copper of cytochrome oxidase and prevents oxygen combining with it [AIIMS 2010]

9. Assertion : Substrate level phosphorylation is present in glycolysis.  
Reason : Substrate level phosphorylation causes synthesis of ATP.
10. Assertion : Under aerobic conditions, pyruvate gives rise to lactate.  
Reason : Under anaerobic condition, pyruvate gives rise to acetyl CoA.
11. Assertion : Terminal oxidation occurs both in aerobic and anaerobic conditions.  
Reason : Terminal oxidation occurs at terminal step of respiration.
12. Assertion : During the hydrolysis of typical chemical bonds, about 3000 calories per mole are liberated.  
Reason : ATP also yields about 3000 calories per mole after the release of any one of the two terminal phosphates.
13. Assertion : Fructose-1, 6 diphosphate is converted into glyceraldehyde-3-phosphate and dihydroxy-acetone-3-phosphate.  
Reason : Conversion of fructose-1,6 diphosphate into 3-phosphoglyceraldehyde and dihydroxyacetone-3-phosphate is facilitated by the enzyme aldolase. [AIIMS 2010]

## Answers

### Anaerobic respiration

1	c	2	d	3	a	4	d	5	c
6	c	7	a	8	a	9	a	10	c
11	a	12	b	13	b	14	b	15	d
16	d	17	d	18	b	19	b	20	b
21	b	22	a						

### Introduction and types of respiration

1	a	2	c	3	d	4	c	5	a
6	d	7	c	8	b	9	d	10	a

11	c	12	b	13	a	14	d	15	c
16	a	17	a	18	b	19	b	20	a
21	d	22	a	23	b	24	b	25	d
26	b	27	c	28	c	29	b	30	a
31	c	32	d	33	b	34	a	35	c
36	c	37	d	38	c	39	c	40	d
41	b	42	d	43	b	44	d	45	c
46	b	47	b	48	d	49	b	50	b
51	c	52	d	53	c	54	a	55	c
56	d	57	a	58	b	59	d	60	a
61	b	62	c	63	b				

### Glycolysis

1	a	2	d	3	a	4	b	5	c
6	a	7	b	8	a	9	b	10	b
11	a	12	c	13	c	14	c	15	b
16	d	17	b	18	b	19	b	20	a
21	b	22	a	23	a	24	a	25	c
26	a	27	a	28	a	29	b	30	d
31	a	32	b	33	a	34	c	35	d
36	a								

### Kreb's cycle and ETS

1	b	2	c	3	a	4	b	5	d
6	a	7	e	8	c	9	b	10	a
11	a	12	a	13	c	14	b	15	d
16	d	17	b	18	a	19	c	20	a
21	b	22	a	23	c	24	b	25	a
26	c	27	b	28	d	29	a, d	30	a
31	a	32	b	33	d	34	a	35	c
36	a	37	a	38	c	39	b	40	d
41	b	42	a	43	c	44	c	45	c
46	b	47	c	48	b	49	a	50	b
51	b	52	e	53	a	54	b	55	a
56	b	57	b	58	d	59	d	60	d
61	c	62	b	63	d	64	c	65	c
66	d	67	a	68	d	69	a	70	b
71	a	72	a	73	d				

## Pentose phosphate pathway

1	b	2	b	3	c	4	a	5	b
6	b	7	c	8	c	9	b	10	c
11	d								

## R.Q.

1	a	2	c	3	d	4	b	5	b
6	d	7	b	8	b	9	b	10	b
11	b	12	b	13	c	14	d	15	c
16	c	17	c	18	c	19	d	20	d
21	a	22	c						

## Factor affecting respiration

1	b	2	b	3	d	4	b	5	b
6	d	7	b	8	d	9	a		

## NCERT Exemplar Questions

1	b	2	c	3	c	4	b	5	a
6	c	7	a	8	d				

## Critical Thinking Questions

1	a	2	a	3	d	4	b	5	c
6	d	7	b	8	a	9	c	10	d
11	c	12	a	13	b	14	c	15	c
16	c	17	c	18	a	19	d	20	b

## Assertion and Reason

1	a	2	a	3	a	4	b	5	c
6	b	7	a	8	b	9	b	10	d
11	a	12	c	13	b				

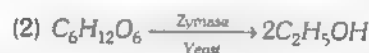


## Answers and Solutions

## Anaerobic respiration

2. (d) *Pasteur's effect*. The increase of rate of glycolysis in absence of  $O_2$  is due to the non-availability of those enzymes which are easily available in presence of  $O_2$ .

6. (c)  $C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2 + 21 Kcal$
8. (a) Cyanide is deadly poison which inhibit the activity of cytochrome oxidase enzyme of electron transport chain. As in case of aerobic respiration there is no electron transport chain involved, therefore, anaerobic respiration is cyanide resistant pathway.
11. (a) In absence of  $O_2$ , fermentation or anaerobic respiration occurs.
13. (b) During anaerobic respiration in yeast glucose formed  $CO_2$ ,  $C_2H_5OH$  and energy.
16. (d) Continuous addition of sugar in 'fed batch' fermentation is done to purify enzymes.
19. (b) Anaerobic respiration first studied by Kostychev (1902).
20. (b) Number of ATP mol. evolved in one complete cycle of anaerobic respiration is 2.
21. (b) In yeast fermentation, the enzymatic reactions are as follows



+  $2CO_2 + 21 kcal$  energy.

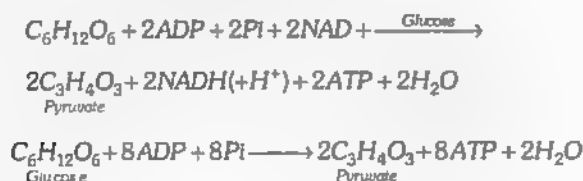
## Introduction and types of respiration

1. (a) Oxysome acts as the unit of phosphorylation in respiration by the formation of ATP from ADP occur on oxysome. These are present on cristae of mitochondria.
3. (d) Respiration rate high at growing regions like floral and vegetative bud, germinating seedlings, young leaves stem and root apices.
11. (c) Two molecules of glycine form a molecule of serine,  $CO_2$  and  $NH_3$  in mitochondria.
14. (d) In submerged hydrophytes (plants which remain completely dipped in the water)  $CO_2$  enters through epidermis as both carbonates and bicarbonates.
17. (a)  $ADP \xrightarrow{\text{hydrolysis}} AMP + Pi + 7.3kcal$ .
18. (b) Chemiosmotic hypothesis of ATP synthesis or oxidative phosphorylation given by Peter mitchell's.
19. (b) In aerobic respiration glycolysis is linked with kreb's cycle through acetyl Co-A because pyruvic acid (end product of glycolysis) first converted into acetyl Co-A. Acetyl Co-A enter in the kreb's cycle. The formation of acetyl Co-A is involved with some cofactors like,  $Mg^{++}$  ions thiamine pyrophosphate, (Vit-B<sub>1</sub>)  $NAD^+$ , Co-A and lipoic acid.
21. (d) ATP was discovered by Lohmann (1926) and ATP cycle by Lipmann (1941) who won Nobel prize in 1953.
23. (b) Cellular respiration is an enzyme controlled process of biological oxidation of food materials in a living cell. Using molecular  $O_2$ , producing  $CO_2$  and  $H_2O$  and releasing energy in small step and storing it in biologically useful forms generally ATP. It occurs in mitochondria.
24. (b) Kreb's cycle takes place in the matrix and ATP formation takes place on oxysome of cristae in mitochondria.

25. (d) Pyruvic acid is the end product of glycolysis. This pyruvic acid forms acetyl CoA. Acetyl CoA is a initial compound of Kreb's cycle.
28. (c) Respiration is a biological enzymatic reaction while combustion is a chemical process.
30. (a) ATP is a higher nucleotide resembling to ribonucleotide having adenine base, ribose sugar and three phosphate groups.
31. (c) Because it takes place in living beings (biological matter).
33. (b) Because kreb's cycle occurs in matrix of mitochondria.
34. (a) According to Lundegarth amount of anion absorbed by plant cells rather than to the absorption of cations of salts so it is also called anion respiration.
37. (d) Aerobic respiration yields  $10\text{NADH}_2$ ,  $2\text{FADH}_2$ ,  $2\text{GTP}$  and  $2\text{ATP}$  resulting into  
 $10\text{NADH}_2 = 10 \times 3 = 30 \text{ ATP}$   
 $2\text{FADH}_2 = 2 \times 2 = 4 \text{ ATP}$   
 $2\text{GTP} = 2 \times 1 = 2 \text{ ATP}$   
 $2\text{ATP} = 2 \times 1 = 2 \text{ ATP}$   
38 ATP
38. (c) Primary respiratory substrate is carbohydrate and secondary respiratory substrate is fat.
52. (d) As 300 ppm is normal concentration of  $\text{CO}_2$ , hence there is no effect on plant.
53. (c) Cellular respiration is an enzyme controlled process of biological oxidation of food materials in living cell.
54. (a) The energy present in one gram of fats is 9.8kcal or 41kJ, which is maximum as compared to another substrate.
57. (a)  $\text{ATP} \xrightarrow{\text{hydrolysis}} \text{ADP} + \text{Pi} + 7.3 \text{ kcal}$
58. (b) Because it is an energy liberating process.

### Glycolysis

4. (b) Two molecules of ATP are consumed in glycolysis during phosphorylation of glucose to fructose 1, 6-diphosphate.
6. (a) Pyruvic acid is end product of glycolysis.
9. (b) Decarboxylation is the removal of carbon from a compound by using carbon to make  $\text{CO}_2$ . During kreb's cycle the acetyl group pass round the cycle and the two carbon atoms are lost in the form of carbon dioxide in two decarboxylation reactions.
10. (b) Glucose - 6-phosphate  $\rightarrow$  3-phosphoglyceraldehyde  $\rightarrow$  3-phosphoglyceric acid  $\rightarrow$  phosphoenol pyruvate  $\rightarrow$  pyruvic acid.
13. (c) Breakdown of glucose into 2 molecules of pyruvic acid is known as glycolysis.
17. (b) The net reaction of glycolysis would be



18. (b) Glycolysis takes place in the cytoplasm and does not use Oxygen. In anaerobic respiration only glycolysis is found, in which there is no need of mitochondria.
19. (b) Glucose is converted into glucose 6-phosphate is first step of glycolysis.
20. (a) Glycolysis occurs in all the living cells because this is common process in both aerobic and anaerobic respiration.
21. (b) Six carbon glucose molecule forms two molecules of three carbon pyruvic acid.  
 $\text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 2\text{C}_3\text{H}_4\text{O}_3 + 4\text{H}$
22. (a) Glycolysis was discovered by Embden, Meyerhof and Parnas.
24. (a) Two molecules of pyruvic acid are formed by one molecule of glucose by glycolysis.
26. (a)  $\text{C}_6\text{H}_{12}\text{O}_6$  is glucose and  $\text{C}_3\text{H}_4\text{O}_3$  is pyruvic acid.
27. (a) EMP pathway is most common which was discovered by Embden, Meyerhof and Parnas (1930).
29. (b) Fructose 6-phosphate + ATP  $\xrightarrow{\text{Phosphofructokinase, Mg}^{2+}}$  Fructose 1, 6-diphosphate + ADP. Glucose is converted into glucose 6-phosphate by ATP in the presence of enzyme hexokinase.
32. (b) Complete oxidation of one molecule of glucose produce 10 molecules of  $\text{NADH}_2$ .

### Kreb's cycle and ETS

2. (c) Malate is dehydrogenated or oxidised through the agency of malate dehydrogenase to produce oxaloacetate
8. (c) Amino acid like aspartate and glutamate on deamination from organic acids like OAA and  $\alpha$ -Ketoglutaric acid respectively which enter into kreb's cycle.
14. (b) If  $\text{O}_2$  is not available pyruvic acid undergo anaerobic respiration/fermentation, but under aerobic condition the pyruvic acid enter into mitochondria and converted to Acetyl Co-A. Acetyl CoA functions as substrate entrant for Krebs cycle. So, a connecting link between glycolysis and Krebs cycle.
21. (b) 1 molecule of glucose yields 56kcal/2ATP in anaerobic respiration and 686000 calories (686 kcal)/total of 38 ATP in aerobic respiration.
22. (a) Under aerobic condition pyruvate is converted into acetyl co-enzyme-A and  $\text{CO}_2$  is released. Acetyl co-enzyme-A combines with oxaloacetic acid and form citric acid.
26. (c) In eukaryotes the entire site of reaction of kreb's cycle occur in the matrix of mitochondria.
28. (d) Largest amount of ATP is produced during aerobic respiration (38 ATP). It includes 8 ATP in glycolysis and 30 ATP in kreb's cycle.
30. (a) Dehydrogenation process converts succinate into 4-carbon fumarate with the aid of an enzyme, succinate dehydrogenase and liberates a pair of hydrogen atoms. The latter pass to  $\text{FAD}^+$  forming  $\text{FADH}_2$ .



38. (c) In aerobic respiration,  $\text{CO}_2$  is produced at 3 step :  
 (i) During acetyl Co-A formation.  
 (ii) During formation of  $\alpha$ -ketoglutaric acid in kreb's cycle.  
 (iii) During succinic acid formation in kreb's cycle.
39. (b) During sixth step succinate is oxidised into fumarate by the enzyme succinate dehydrogenase and two hydrogens are transferred to FAD to form  $\text{FADH}_2$ .
46. (b) Reductive amination is the method of amino-acid synthesis in plants. In this method,  $\alpha$ -keto glutaric acid reacts with ammonia ( $\text{NH}_3$ ) and forms the amino acid called glutamic acid. The enzyme glutamate dehydrogenase enhances the reaction.
57. (b) Cytochrome  $a_3$  is terminal cytochrome of ETC. It has  $\text{Fe}^{+++}$  and  $\text{Cu}^{++}$  both. With  $\text{Fe}^{+++}$ , it picks up electrons and through  $\text{Cu}^+$  it passes electrons to oxygen.
61. (c) Kреб's cycle is an important step of aerobic respiration in which largest molecules of ATP are formed.
62. (b) These are arranged in order of their increasing redox potential and electron flow through the chain in step wise manner from the more electronegative compound to the more electropositive  $\text{O}_2$ . On the basis of redox potential cytochrome acceptor order is  $\text{cyt b c a a}_3$ .
64. (c) Fe-S complex is responsible for passing electrons (also protons) from mitochondria NADH/NADPH to ubiquinone.
65. (c) In aerobic conditions pyruvic acid formed in glycolysis enters in the matrix of mitochondria.
66. (d) Succinyl CoA  $\xrightarrow[\text{GDP} + \text{P}]{\text{H}_2\text{O} \quad \text{GTP}}$  succinic acid.
67. (a) ATP is not electron transferring molecule. It is a energy storing molecule. So it is called as currency of energy.
68. (d) Cytochromes contain Fe with porphyrin pigment. The electrons pass through the cytochromes reducing their  $\text{Fe}^{+3}$  into  $\text{Fe}^{+2}$  ( $\text{Fe}^{+3} + e^- \rightarrow \text{Fe}^{+2}$ ).
69. (a) Cytochromes occur in cristae of mitochondria because all cytochromes involved in electron transport system.
70. (b) The oxygen is the terminal acceptor of electrons which forms a water molecule in presence of protons in ETS  

$$\left( \frac{1}{2} \text{O}_2 + 2e^- \rightarrow \text{O}^{2-}, 2\text{H}^+ + \text{O}^{2-} \rightarrow \text{H}_2\text{O} \right)$$

### Pentose phosphate pathway

3. (c) The complete oxidation of one glucose molecule forms 12NADPH which are equivalent to 36 ATP molecules.
5. (b) PPP provides erythrose- 4 - phosphate which is required for the synthesis of shikimic acid. The latter is a precursor of aromatic ring compounds.
6. (b) HMP is an alternate method of aerobic respiration and occurs in cytoplasm.
9. (b) PEP was described by Warburg (1935) and Dickens (1938).

### R.Q.

1. (a)  $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \longrightarrow 6\text{CO}_2 + 6\text{H}_2\text{O}$   

$$\text{R.Q.} = \frac{\text{Vol. of CO}_2}{\text{Vol of O}_2} = \frac{6}{6} = 1$$
3. (d) In the above green organs the value of R.Q. is always one because in them for respiration hexose molecule is needed, in which  $\text{CO}_2$  and  $\text{O}_2$  molecules are equal.
5. (b) Since amount of  $\text{CO}_2$  released is less than absorbed  $\text{O}_2$ , therefore the value of  $\text{RQ} \left( \frac{\text{CO}_2}{\text{O}_2} \right)$  is less than unity.
7. (b) 
$$\frac{\text{Vol. of CO}_2}{\text{Vol. of O}_2} = \frac{V_2 \text{ cc}}{V_1 \text{ cc} + V_2 \text{ cc}}$$
  

$$\Rightarrow \text{R.Q.} = \frac{30 \text{ cc}}{10 \text{ cc} + 30 \text{ cc}} = 0.75$$
10. (b) During anaerobic respiration, due to the absence of  $\text{O}_2$  the value of R.Q. is infinite (or more than one).  

$$\text{C}_6\text{H}_{12}\text{O}_6 \longrightarrow 2\text{CO}_2 + 2\text{C}_2\text{H}_5\text{OH}$$
  

$$\text{R.Q.} = \frac{2}{\square} = (\text{infinite}).$$
11. (b) Respiratory quotient depends upon the type of substrate participating in respiration.
13. (c) Carbohydrate  

$$\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{Energy}$$
  

$$\text{RQ} = \frac{6\text{CO}_2}{6\text{O}_2} = 1$$
  
 Fats : The value of RQ is less than 1. This would mean that there is much less oxygen in the constitution of fat as compared to that in carbohydrates. Thus, they need more  $\text{O}_2$  for respiration.  
 As an example, the equation for respiration of Tripalmitin is as under  

$$2(\text{C}_{51} \text{H}_{98} \text{O}_6) + 145 \text{O}_2 \rightarrow 102 \text{CO}_2 + 98 \text{H}_2\text{O} + \text{Energy}$$
  

$$\text{RQ} = \frac{102 \text{CO}_2}{145 \text{O}_2} = 0.7.$$
14. (d) In some succulent or fleshy plants e.g., *Opuntia*, carbohydrates are incompletely oxidized to organic acids in dark without the evolution of  $\text{CO}_2$   

$$\underset{\text{glucose}}{2\text{C}_6\text{H}_{12}\text{O}_6} + 3\text{O}_2 \longrightarrow \underset{\text{malic acid}}{3\text{C}_4\text{H}_6\text{O}_5} + 3\text{H}_2\text{O}$$
  

$$\text{R.Q.} = \frac{\text{CO}_2}{\text{O}_2} = \frac{0}{3} = 0 \text{ (less than one)}$$
17. (c) In germinating castor seeds, respiratory substrate is fat. Maize contains carbohydrate and groundnut seed contains fatty acid. R.Q. of these substances are respectively less than 1. Thus total R.Q. will be less than one.
18. (c)  $\text{C}_4\text{H}_6\text{O}_5 + 3\text{O}_2 \longrightarrow 4\text{CO}_2 + 3\text{H}_2\text{O}$   

$$\text{R.Q.} = \frac{4}{3} = 1.3 \text{ (more than one).}$$

## Factor affecting respiration

3. (d) In apple, gaseous hormone ethylene is produced which helps in ripening of banana to convert it yellow.
5. (b) If the amount of  $\text{CO}_2$  in the air more than usual rate of respiration is decreased.
7. (b) Oxygen is essential for aerobic respiration it is the ultimate acceptor of electrons in electron transport system (E.T.S)
8. (d) Water is essential for accelerating enzyme activity. In conditions of water stress therefore the respiration decreases that's why in dry fruits and seeds in respiratory enzyme least active, show minimum respiration.
9. (a) Cyanides, azides and carbon monoxide work as enzyme inhibitors, thus the rate of respiration decreases.

## Critical Thinking Questions

14. (c) At low temperature in green apple, the galactose sugar consumption reduces in respiration due to which they remain as such fresh for long time.

15. (c) Reaction of respiration is



In this reaction considering molecular weight of each element, we get

$$\text{C}_6\text{H}_{12}\text{O}_6 = 6 \text{ times } 12 + 12 \text{ times } 1 + 6 \text{ times } 16 = 180 \text{ gm}$$

$$\text{O}_2 = 6 \text{ times } 32 = 192 \text{ gm}$$

Now we consider products of this reaction i.e.  $6\text{CO}_2$  and  $6\text{H}_2\text{O}$

$$6\text{CO}_2 = 6 (12 + 32) = 264 \text{ gm}$$

$$6\text{H}_2\text{O} = 6 (2 + 16) = 108 \text{ gm}$$

17. (c)  $2\text{C}_{39}\text{H}_{72}\text{O}_6 + 108\text{O}_2 \rightarrow 78 \text{ CO}_2 + 72 \text{ H}_2\text{O}$

$$\therefore \text{R.Q.} = \frac{\text{Volume of CO}_2 \text{ evolved}}{\text{Volume of O}_2 \text{ used up}} = \frac{78}{108} = 0.72$$

## Assertion and Reason

1. (e) Alcoholic fermentation is the respiration in absence of  $\text{O}_2$ . In this process, hexose molecule is changed to ethyl alcohol and  $\text{CO}_2$ . In presence of zymase enzyme. In this less amount of energy is released as compared to aerobic respiration.
2. (a) Glycolysis occurs in cytoplasm as all necessary enzymes are found in it. This process is common in aerobic/anaerobic respiration. In this process, one glucose molecule is converted into 2 molecules of pyruvic acid.
3. (e) The passage of electrons from one enzyme or cytochrome to the next is a downhill journey with a loss of energy at each step. At each step the electron carriers include flavins, iron sulphur complexes, quinones and cytochromes.

4. (b) The inner membranes of mitochondria contain all systems involving electron transport. The mitochondrial matrix contains all the soluble enzymes of the citric acid or Krebs cycle and those involved in the oxidation of fatty acids.
5. (c) Both kinases require a divalent cation ( $\text{Mg}^{2+}$  or  $\text{Mn}^{2+}$ ), which first combines with ATP to form the true substrate,  $\text{MgATP}^{2-}$  or  $\text{MnATP}^{2-}$ .
6. (b) One way of indicating the ATP yield from oxidative phosphorylation is the P/O ratio, which is expressed as the moles of inorganic phosphate used per oxygen atom consumed. The cell stores 40% of the chemical energy liberated by the combustion of glucose in the form of ATP. The rest of the energy is dissipated as heat or used for other cell functions.
7. (e) The cytochromes are a group of iron containing electron-transferring proteins of aerobic cells that act sequentially to transfer electrons from flavoprotein to molecular oxygen. The terminal cytochrome of the electron transport chain, which can react with oxygen, is called cytochrome oxidase.
8. (b) The final stage of respiratory chain involves cytochrome oxidase which contains copper. This stage can be specifically inhibited by cyanide or carbon monoxide. Cyanide combines with the copper and prevents oxygen combining with it.
9. (b) One of the two phosphates of diphosphoglycerate is linked by high energy bond. It can synthesize ATP and form 3-phosphoglycerate. The enzyme is phosphoglycerate kinase. The direct synthesis of ATP from metabolites is called substrate level phosphorylation.
10. (d) Under aerobic conditions, the products are pyruvate and coenzyme NADH. Pyruvate directly enters the mitochondrial matrix and is converted into acetyl-CoA. Under anaerobic conditions, pyruvate is used as a hydrogen acceptor and converted into lactate. In anaerobic conditions, pyruvate remains in the cytosol.
11. (e) Terminal oxidation is the name of oxidation found in aerobic respiration that occurs towards the end of catabolic process and involves the passage of both electrons and protons of reduced coenzymes to oxygen.
12. (c) During the hydrolysis of typical chemical bonds, about 3000 calories per mole are liberated. The release of any one of the two terminal phosphates of ATP yields about 7300 calories per mole, instead of the 3000 calories from common chemical bonds. The standard free energy of hydrolysis of ATP to ADP and phosphate is  $-7.30 \text{ K cal}$  at pH 7.0 and temperature  $37^\circ\text{C}$  in the presence of excess  $\text{Mg}^{2+}$ .
13. (b) Fructose 1, 6-diphosphate in the presence of enzyme aldolase is converted into a glyceraldehyde-3-phosphate and a dihydroxy acetone-3-phosphate molecules.



## Respiration in Plants

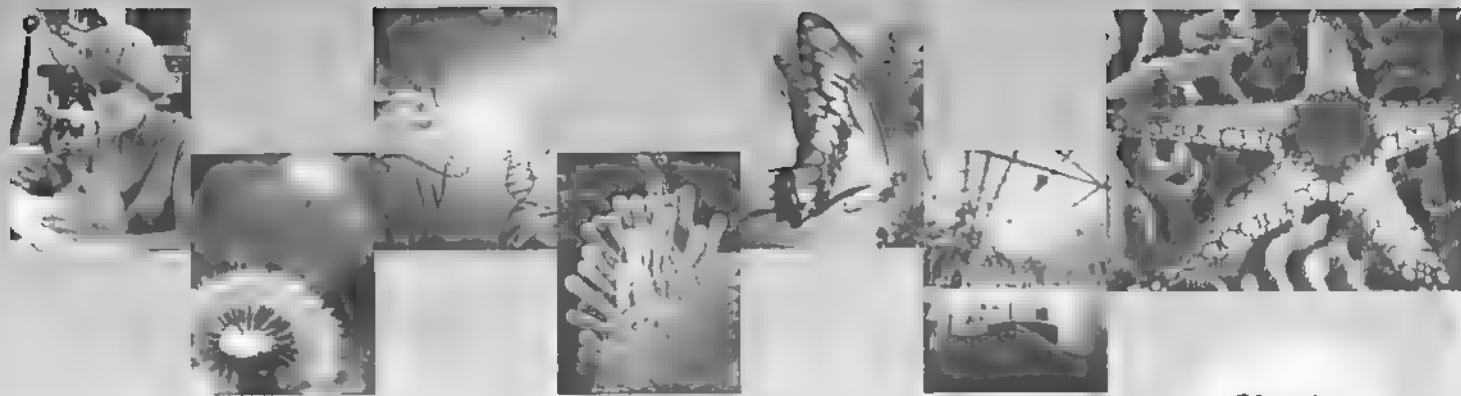
## Self Evaluation Test

- Enzymes found attached to inner membrane of mitochondria instead of matrix is/are [AFMC 2006]
  - Succinic dehydrogenase
  - Cytochrome oxidase
  - Both (a) and (b)
  - Malic dehydrogenase
- Anaerobic respiration is also known as
  - Intramolecular respiration
  - Intermolecular respiration
  - Extramolecular respiration
  - Molecular respiration
- The process by which ATP is produced in the inner membrane of a mitochondrion. The electron transport system transfers protons from the inner compartment of the outer, as the protons flow back to the inner compartment, the energy of their movement is used to add phosphate to ADP, forming ATP [AIIMS 2009]
  - Chemiosmosis
  - Phosphorylation
  - Glycolysis
  - Fermentation
- Which of the following processes make direct use of oxygen [Kerala PMT 2006; CPMT 2010]
  - Glycolysis
  - Fermentation
  - Electron transport
  - Kreb's citric acid cycle
  - Hydrolysis
- What is active glucose
  - FAD-glucose
  - NAD-glucose
  - Phosphoglucose
  - Glycerophosphate
- High fatty acids are breaking by [RPMT 1999]
  - $\beta$ -oxidation
  - $\alpha$ -oxidation
  - Glycolysis
  - All of these
- How many ATP will be produced during the production of 1 molecule of acetyl CoA from 1 molecule of pyruvic acid [MP PMT 1996, 2006]
  - 3 ATP
  - 5 ATP
  - 8 ATP
  - 38 ATP
- Fruit keep better in refrigeration, this is due to
  - Non-availability of  $O_2$
  - Absence of moisture
  - Accumulation of  $O_2$
  - Inactivation of respiration
- Vant Hoff's law states that [KCET 1994]
  - The respiration rate increases two or three times for every rise of  $5^\circ C$
  - The respiration rate decreases two or three times for every rise of  $10^\circ C$
  - The respiration rate does not increase or decrease with change in temperature
  - The respiration rate increases two or three times for every rise of  $10^\circ C$
- A characteristic feature of ripening of some fruits (like banana) is a sudden increase in respiration which is known as
  - Climacteric
  - Anthesis
  - Climatic
  - Photorespiration
- R.Q. is highest when respiratory substance is
  - Fat
  - Malic acid
  - Glucose
  - Protein
- An indispensable role in energy metabolism is played by
  - Sodium
  - Phosphorus
  - Calcium
  - Potassium
- Fermentation is conducted by [NCERT]
  - All fungi
  - All bacteria
  - Some fungi and some bacteria
  - All micro-organisms

## Answers and Solutions

1	c	2	a	3	a	4	c	5	c
6	a	7	a	8	d	9	d	10	a
11	b	12	b	13	c				

- (c) All the enzymes of Kreb's cycle, fatty acid synthesis and amino acid synthesis are found in matrix but succinic dehydrogenase and cytochrome oxidase are present on inner membrane of mitochondria.
- (a) Chemiosmosis is the diffusion of ions across a selectively-permeable membrane. More specifically, it relates to the generation of ATP by the movement of hydrogen ions across a membrane during cellular respiration
- (a) Fats hydrolyse in fatty acids and glycerol. Fatty acids after  $\beta$ -oxidation forms to acetyl CoA and glycerol forms to triose phosphates.
- (a) During acetyl CoA formation by pyruvic acid, only one  $NADH_2$  is formed by which 3 molecules of ATP are formed
- (d) Respiratory rate is low in refrigeration.
- (d) The respiration rate increases two or three times for every rise of  $10^\circ C$  called or Vant Hoff's law which is between 2 to 2.5.
- (a) Some fruits (e.g., banana and apple) show high rates of respiration during their ripening. This rise in respiratory rate is called climacteric.
- (b) Because malic acid is an organic acid, which after oxidation produces more  $CO_2$ , due to which the value of R.Q. is four.
- (b) Because phosphorus produces energy coins ATP.
- (c) Fermentation is anaerobic breakdown of carbohydrates into alcohol, organic acids with the help of microorganisms (fungi, bacteria).



## Chapter

# 4.5

## Plant Growth and Development

Growth can be defined as a vital process which brings about irreversible permanent change in any plant or its part with respect to its size, form, weight and volume.

**Regions of growth :** In unicellular plants there is overall growth and not confined to any specific region but in multicellular plants growth is restricted to specific regions having meristematic cells. On the basis of their position in the plant body (higher plants) meristems are divided into three main categories.

(1) **Apical meristems :** These meristems are found at shoot and root apex. As a result of activity of these meristems plant increases in length. In angiosperms and gymnosperms there is a group of meristematic cells but in bryophytes and pteridophytes there is a single tetrahedral cell found at the shoot apex.

(2) **Intercalary meristems :** These meristems are found above the nodes. As a result of the activity of these meristems increase in length takes place. e.g., *Bambusa*.

(3) **Lateral meristems. :** These meristems are made up of cells which divide in radial direction only. They form laterally placed new cells towards the centre and periphery. Cork cambium (phellogen) and vascular cambium are the examples of lateral meristems. Increase in girth of shoots and roots take place because of the activity of this cambium.

### Phases of growth

(1) **Cell division (Formative phase) :** Growth is based on mitotic cell division.

(2) **Cell enlargement :** Cell division is followed by cell enlargement. The cell increases in size due to vacuolation (by absorption of water). The cell enlargement has been explained in two different ways. According to the first view, the turgor of the cell is responsible for cell enlargement. The other view considers that as a result of growth of the cell wall the volume of the cell increases.

(3) **Cell maturation (Differentiation) :** Cell differentiation followed by cell division and cell enlargement leads to the development of specialized mature tissue cell. e.g., xylem tracheids and trachea, sieve tubes and companion cells.

**Growth curve :** The rate of growth varies in different species and different organs. The young leaf sheath of banana grows for a time at the rate of almost three inches per hour. Growth begins slowly, then enters a period of rapid enlargement, following which it gradually decreases till no further enlargement occurs. The mathematical curve which represents this variation in growth rate is some what flattened S-shaped curve or sigmoid curve. Time in which growth takes place has been called grand period of growth. This term was coined by Sachs. The analysis of growth curve shows that it can be differentiated into three phases .

(1) **Lag phase :** The rate of growth is very slow in lag phase. More time is needed for little growth in this phase.

(2) **Log phase (Exponential phase) :** The growth rate becomes maximum and more rapid. Physiological activities of cells are at their maximum. The log phase is also referred to as grand period of growth

(3) **Final steady state (Stationary phase) or Adult phase :** When the nutrients become limiting, growth slows down, so physiological activities of cells also slows down. This phase indicates maturity of growth system. The rate of growth can be measured by an increase in size or area of an organ of plant like leaf, flower, fruit etc. The rate of growth is called efficiency index.

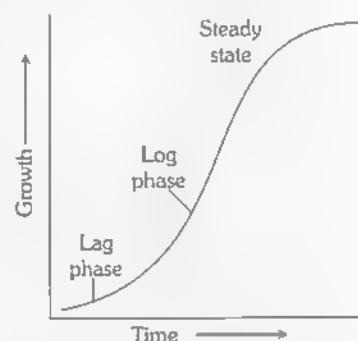


Fig : 4.5-1 A typical S-shaped grand period of growth curve

In many plants another phase is also evident in their growth curve. This is called linear phase or phase of maximum growth rate Sachs called it as grand phase.

### Measurement of growth

The following methods are designed to measure growth in length :

(1) **Direct method** : Measurement is done between two marked points by a scale at regular intervals.

(2) **Horizontal microscope (Travelling microscope)**

(3) **Auxanometer** : Several kinds of auxanometers have been devised to measure the growth in length of a plant. Two of them are :

(i) **Arch auxanometer**

(ii) **Pfeffer's auxanometer (Automatic auxanometer)**

(4) **Bose's crescograph** : The crescograph invented by Sir Jagdish Chandra Bose is a more delicate instrument and gives magnification upto 10,000 times. The rate of growth of root can be measured by the use of a root auxanometer.

**Factors influencing rate of growth** : Growth is affected by the factors which affect the activity of protoplasm. It is affected by a large number of factors both environmental and physiological. Physiological factors such as absorption of water, minerals, photosynthesis, respiration etc, and environmental factors including climatic and edaphic both. The effect on these factors on one region of plant are also transmitted to other region of the plant.

Since growth is a resultant of many metabolic processes, it is affected by many external and internal factors, which are as follows :

### External factors

(1) **Light** : Light affects variously e.g., light intensity, quality and periodicity.

(i) **Intensity of light** : In general, light retards growth in plants. High light intensities induce dwarfing of the plant. Plants at hill tops are short whereas those of a valley are quite tall. Very weak light induces the rate of overall growth and also photosynthesis. Development of chlorophyll is dependent on light and in its absence etiolin compounds are formed which gives yellow colour to the plant. The phenomenon is called etiolation. Similarly high light intensity affects indirectly and increases the rate of water loss and reduces the rate of water growth.

(ii) **Quality of light** : The different colours (different wavelengths) affect the growth of plant. In blue-violet colour light internodal growth is pronounced while green colour light reduces the expansion of leaves as compared to complete spectrum of visible light. The red colour light favours elongation but they resemble etiolated plants. Infrared and ultraviolet are detrimental to growth. However, ultraviolet rays are necessary for the development of anthocyanin pigments in the flowers. Blue and violet colour increases size of lamina of leaf.

(iii) **Duration of light** : There is remarkable effect on duration of light on the growth of vegetative as well as reproductive structures. The induction and suppression of flowering are dependent on duration. The phenomenon is termed photoperiodism.

(2) **Temperature** : Temperature has pronounced effect on the growth of plant. The temperature cardinals for growth vary according to temperature zones. The minimum, optimum and maximum temperatures are usually 5°C (arctic), 20 – 30°C (temperate) and 35 – 40°C (tropical). The optimum temperature needed for the growth of a plant is much dependent on the stages of development.

(3) **Water** : As water is an essential constituent of the living cell, a deficiency of water causes stunted growth.

(4) **Oxygen** : In poorly aerated soil there is low concentration of oxygen and a high concentration of CO<sub>2</sub>. Under such conditions plants usually show stunted growth. Normal growth of most plants occurs only when abundant oxygen is present since O<sub>2</sub> is important for respiration. It has been reported that oxygen plays some important role during G<sub>1</sub> stage of cell division.

(5) **Mineral salt** : Absence of essential mineral salts results in abnormal growth. For example, the absence of nitrogen prevents protein-synthesis, while the absence of iron prevents chlorophyll formation and thus leads to pale and sickly growth of plants, known as chlorotic condition.

(6) **Pollutants** : Several pollutants such as automobile exhaust, peroxyacetyl nitrate (PAN), pesticides etc have detrimental effect on plant growth. Citrus and Gladiolus are very sensitive to fluorides. Poor growth of tobacco is observed in regions where ozone concentration is high. White pine cannot survive under high O<sub>3</sub> concentration. Cotton plants are similarly very sensitive to ethylene.

(7) **Carbon dioxide** : CO<sub>2</sub> is essential for photosynthesis and hence nutrition. Due to change in photosynthetic rate, with the increase or decrease in CO<sub>2</sub> concentration, the plant growth is also affected.

### Internal factors

(1) **Nutrition** : It provides raw material for growth and differentiation as well as source of energy. C/N (Carbohydrate/Nitrogen) ratio determines the type of growth. High C/N ratio stimulates wall thickening. Less protoplasm is formed. Low C/N ratio favours more protoplasm producing thin walled soft cells. According to law of mass growth, the initial rate of growth depends upon the size of germinating structure (seed, tubes, rhizome, bulb, etc.)

(2) **Growth regulators** : These are manufactured by living protoplasm and are important internal growth regulators which are essential for growth and development. These growth regulators include several phytohormones and some synthetic substances.

### Differentiation, Dedifferentiation and Redifferentiation

The cells derived from root apical and shoot-apical meristems and cambium differentiate and mature to perform specific functions. This act leading to maturation is termed as **differentiation**. During differentiation, cells undergo few to major structural changes both in their cell walls and protoplasm. For example, to form a tracheary element, the cells would lose their protoplasm. They also develop a very strong, elastic, lignocellulosic secondary cell walls, to carry water to long distances even under extreme tension.

Plants show another interesting phenomenon. The living differentiated cells, that by now have lost the capacity to divide can regain the capacity of division under certain conditions. This phenomenon is termed as **dedifferentiation**. For example, formation of meristems – interfascicular cambium and cork cambium from fully differentiated parenchyma cells. While doing so, such meristems/tissues are able to divide and produce cells that once again lose the capacity to divide but mature to perform specific functions, i.e., get **redifferentiated**.

### Growth hormones and Growth regulators

The term hormone was first used by Starling (1906). He called it stimulatory substance. The growth and development in plants is controlled by a special class of chemical substances called hormones. They are needed in small quantities at very low concentrations as compared to enzyme. They are rarely effective at the site of their synthesis.

Thus, growth hormones are also called phytohormones term given by Thimann (1948), it can be defined as 'the organic substances which are synthesized in minute quantities in one part of the plant body and transported to another part where they influence specific physiological processes'. A group of plant hormones including auxins, gibberellins, cytokinins, ethylene and abscisic acid are presently known to regulate growth.

**Auxins** : Auxins (Gk. auxein = to grow) are weakly acidic growth hormones having an unsaturated ring structure and capable of promoting cell elongation, especially of shoots (more pronounced in decapitated shoots and shoot segments) at a concentration of less than 100 ppm which is inhibitory to the roots. Among the growth regulators, auxins were the first to be discovered.

**Discovery** : Julius Von Sachs was the first to indicate the presence of organ forming substances in plants. The existence of first plant growth hormone came from the work of Darwin and Darwin (1881). Darwin described the effects of light and gravity in his book, "Power of movements in plants". Darwin and his son found that bending movement of coleoptile of Canary grass (*Phalaris canariensis*) was due to exposure of tip to unilateral light. Boysen-Jensen (1910; 1913) found that the tip produces a chemical which was later named auxin. Paal (1914, 1919) removed coleoptile tip and replaced it asymmetrically to find a curvature. Auxin was first collected by Went (1928) from coleoptile tip of *Avena*. Went also developed *Avena* curvature test for bioassay of auxin.

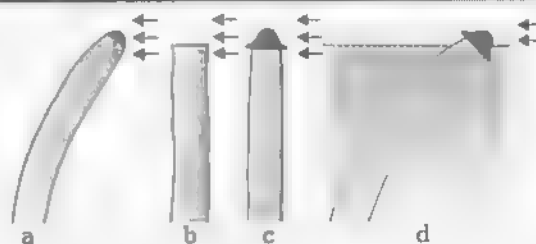
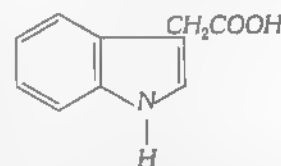


Fig : 4.5-2 Experiment used to demonstrate that tip of the coleoptile is the source of auxin. Arrows indicate direction of light

**Types of auxins** : There are two major categories of auxins natural auxins and synthetic auxins.

(1) **Natural auxins** : These are naturally occurring auxins in plants and therefore, regarded as phytohormones. Indole 3-acetic acid (IAA) is the best known and universal auxin. It is found in all plants and fungi.

The first naturally occurring auxin was isolated by Kogl and Haagen-Smith (1931) from human urine. It was identified as auxin-a (auxenotonic acid,  $C_{10}H_{12}O_2$ ). Later, in 1934 Kogl, Haagen-Smith and Exleben obtained another auxin, called auxin-b



Indole acetic acid (IAA)

(auxenotonic acid,  $C_{10}H_{12}O_4$ ) from corn germ oil (extracted from germinating corn seeds), and heteroauxin from human urine. Heteroauxin ( $C_{10}H_9O_2N$ ) also known as indole-3-acetic acid (IAA), is the best known natural auxin. Besides IAA, indole-3-acetaldehyde, indole-3-pyruvic acid, indole ethanol, 4-chloro-indole acetic acid (4-chloro-IAA) etc., are some other natural auxins.

Natural auxins are synthesized (Young) in physiologically active parts of plants such as shoot apices, leaf primordia and developing seeds, buds (apex), embryos, from amino acid tryptophan. In root apices, they are synthesized in relatively very small amount. Auxins show polar movement. It is basipetal (from apex to base) in stem but acropetal (from root tip towards shoot) in the root. Auxins move slowly by diffusion from cell to cell and not through the vascular tissues. Auxins help in the elongation of both roots and shoots. However, the optimum concentration for the two is quite different.

It is 10 ppm for stem and 0.0001 ppm for the root. Higher concentration of auxins show inhibitory effect on growth.

(2) **Synthetic auxins** : These are synthetic compounds which cause various physiological responses common to IAA. Some of the important synthetic auxins are 2, 4-D (2, 4-dichlorophenoxy acetic acid) is a weedicide, 2, 4, 5-T (2, 4, 5-trichlorophenoxy acetic acid), IBA (indole 3-butyric acid), NAA (naphthalene acetic acid, PAA (Phenyl acetic acid), IPA (Indole 3-propionic acid). IBA is both natural and synthetic auxin. Certain compounds inhibit action of auxin and compete with auxins for active sites and are called antiauxins. e.g., PCIB (p-chlorophenoxy isobutyric acid), TIBA (2, 3, 5-tri iodobenzoic acid). TIBA is used in picking cotton balls.

**Bioassay of Auxins** : Testing of biological activity (growth) of a substance (auxin) by employing living material is called bioassay.

(1) ***Avena* coleoptile curvature test** : *Avena* curvature test carried out by F.W. Went (1928) demonstrated the effect of auxins on plant growth by performing some experiments with the oat (*Avena sativa*) coleoptile.

(2) **Split pea stem curvature test** : This test was also discovered by Went, 1934.

(3) **Root growth inhibition test (Cress root inhibition test)**

**Functions of auxins** : Auxins control several kinds of plant growth processes. These are as follows :

(1) **Cell elongation** : Auxins promote elongations and growth of stems and roots and enlargement of many fruits by stimulating elongation of cells in all directions.

The auxins cause cell enlargement by solubilisation of carbohydrates, loosening of microfibrils, synthesis of more wall materials, increased membrane permeability and respiration.

(2) **Apical dominance** : In many plants, the apical bud grows and the lower axillary buds are suppressed. Removal of apical bud results in the growth of lower buds. The auxin (IAA) of the terminal bud inhibits the growth of lateral buds. This phenomenon is known as apical dominance.

This property of auxins has found use in agriculture. Sprouting of lateral buds (eyes) of the potato tuber is checked by applying synthetic auxin (NAA).

Moving on a grass lawn facilitates better maintenance primarily owing to removal of apical dominance.

(3) **Control of abscission layer** : Auxin inhibits abscission of leaves and fruits. Abscission layer is produced when the auxin content falls below a minimum.

Premature drop of fruits such as apple, pear and citrus can be prevented to a great extent by spraying the trees with a dilute solution of IAA, NAA or some other auxin.

(4) **Weed control** : By the spray of 2, 4-D, broad-leaved weeds can be destroyed but 2, 4-D does not affect mature monocotyledonous plants.

(5) **Root differentiation** : Many new plants are usually propagated by stem cutting e.g., Rose, Bougainvillea. If we dip the lower cut end of a cutting in dilute solution of auxins (specially IBA gives very good results) very soon large number of roots are developed on the cut ends due to which these cuttings develop into successful plants.

(6) **Parthenocarpy** : Parthenocarpy can be induced by application of IAA in a paste form to the stigma of a flower or by spraying the flowers with a dilute solution of IAA. Banana, oranges and grapes are now-a-days grown parthenocarpically on commercial scale. Auxins are applied in lanolin paste on stigma for inducing parthenocarpy.

(7) **Control of lodging** : In some plants when the crop is ripe and there is heavy rain accompanied by strong winds, the plants bend as a result of which the ear (inflorescence) gets submerged in water and decays. If a dilute solution of any auxin is sprayed upon young plants the possibility of bending of plants is reduced as the stem becomes stronger by the application of auxins.

(8) **Flowering** : In pineapple, NAA promotes flowering. In lettuce, auxins help in delaying the flowering. In cotton plants, the use of auxins increases the cotton seeds production.

(9) **Differentiation of vascular tissues** : Auxins induce the differentiation of xylem and phloem in intact plants and also in callus produced *in vitro* during tissue culture experiments.

(10) **Sex expression** : The spray of auxins increases the number of female flowers in cucurbits. In maize, application of NAA during the period of inflorescence differentiation can induce formation of hermaphrodite or female flowers in a male inflorescence.

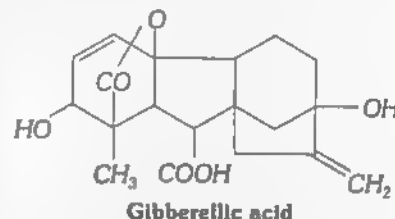
Thus auxins cause femaleness in plants.

(11) **Healing** : Healing of injury is effected through auxin induced division in the cells around the injured area. The chemical was formerly named traumatic acid or traumatin.

(12) **Nodule formation** : In legumes, IAA is known to stimulate nodule formation.

(13) **Respiration** : According to French and Beevers (1953) the auxin may increase the rate of respiration indirectly through increased supply of ADP by rapidly utilizing the ATP in the expanding cells.

**Gibberellins** : Gibberellins are weakly acidic hormones having gibbane ring structure which cause cell elongation of intact plants in general and increased internodal length of genetically dwarfed plants (i.e., corn, pea) in particular.



**Discovery** :

Gibberellins were first isolated from the fungus *Gibberella fujikuroi* (*Fusarium moniliforme*) the causal organism of Bakanae disease or foolish seedling disease of rice plants in Japan by Kurosawa in 1926.

In 1939, Yabuta and Sumiki and coworkers working in Tokyo isolated an active substance from the fungus and called it Gibberellin A. This gibberellin preparation was probably a mixture of several gibberellins. The first gibberellin to be obtained was Gibberellin A-3. Cross *et al.* (1961) explained the detailed structure of gibberellic acid. Now 60 gibberellins have been identified from different groups of plants.

Many of them occur naturally in plants. *Gibberella fujikuroi* has as many as 15 gibberellins. All the different types of gibberellins, known so far, have gibbane skeleton and are acidic in nature. Anti-gibberellins like malic hydrazide, phosphon D, Alar and chorocholine cheoride (CCC) or cycocel are also called antiretardants (stimulates flowering and inhibits the growth of nodes). Commercial production of GA is still carried out by culturing this fungus in large vats.

**Bioassay of gibberellin** : Gibberellin bioassay is performed through dwarf maize/pea test and cereal endosperm test.

**Functions of gibberellin**

(1) **Stem elongation** : The gibberellins induce elongation of the internodes. The elongation of stem results due to rapid cell division and cell elongation induced by gibberellins.

(2) **Leaf expansion** : In many plants leaves become broader and elongated when treated with gibberellic acid. This leads to increase in photosynthetic area which finally increases the height of the plant. Interestingly, gibberellins show no effect on roots.

(3) **Reversal of dwarfism** : One of the most striking effects of gibberellins is the elongation of genetic dwarf (mutant) varieties of plants like corn and pea. It is believed that dwarfism in the mutant variety of plant is due to blocking of the capacity for normal gibberellin production (deficiency of gibberellin). When gibberellin is applied to single gene dwarf mutants e.g., *Pisum sativum*, *Vicia faba* and *Phaseolus multiflorus*, they grow to their normal heights. It is further interesting to note that application of gibberellins to normal plants fail to show any remarkable effects.



(4) **Bolting** : Gibberellins induce stem elongation in 'rosette plants' e.g., cabbage, henbane, etc. Such plants show retarded internodal growth and profuse leaf development. In these plants just prior to the reproductive phase, the internodes elongate enormously causing a marked increase in stem height. This is called bolting.

Bolting needs long days or cold nights. It has been further noticed that if cabbage head is kept under warm nights, it remains vegetative. The exogenous application of gibberellins induced bolting in first year itself in plants like cabbage (normally bolting occurs next year due to effect of endogenous gibberellins).

(5) **Flowering** : Gibberellins also play an important role in the initiation of flowering. Lang (1960) demonstrated that added gibberellin could substitute for the proper environmental conditions in *Hyoscyamus niger* which requires long day treatment for flowering. Such effects of gibberellin are common among vernalised and long day plants.

Gibberellin is also known to play essential role in germination of cereal seeds.

(6) **Enzyme formation** : One of the most dramatic effects of GA is its induction of hydrolytic enzymes in the aleurone layer of endosperm of germinating barley seeds and cereal grains. GA stimulates the production of digestive enzymes like proteases,  $\alpha$ -amylases, lipases which help to mobilise stored nutrients. GA treatment stimulates a substantial synthesis of new mRNA. Thus GA acts to uncover or depress specific genes, which then cause the synthesis of these enzymes. It is assumed that GA acts on the DNA of the nucleus.

(7) **Breaking of dormancy** : Gibberellins overcome the natural dormancy of buds, tubers, seeds, etc. and allow them to grow. Sprouting of potato in cold storage occur due to GA. In this function gibberellins act antagonistically to abscisic acid (ABA).

(8) **Parthenocarp** : Gibberellins have been considered to be more effective than auxins for inducing parthenocarp in fruits like apple, tomato and pear. GA application has also resulted in the production of large fruits and bunch length in seedless grapes.

(9) **Sex expression** : Gibberellins control sex expression in certain plants. In general, gibberellin promote the formation of male flowers either in place of female flowers in monoecious plants such as cucurbits or in genetically female plants like *Cannabis*, *Cucumis*.

(10) **Substitution for vernalization** : Vernalization is the low temperature requirement of certain plant (i.e., biennials) to induce flowering. The low temperature requirement of biennials for flowering can be replaced by gibberellins.

(11) **Malt yield** : There is increased malt production when gibberellins are provided to germinating barley grains (due to greater production of  $\alpha$ -amylase).

(12) **Delayed ripening** : Ripening of citrus fruits can be delayed with the help of gibberellins. It is useful in safe and prolonged storage of fruits.

(13) **Seed germination** : Gibberellins induce germination of positively photo-blastic seeds of lettuce and tobacco in complete darkness.

**Cytokinins (Phytokinins)** : Cytokinins are plant growth hormones which are basic in nature, either aminopurine or phenyl urea derivatives that promote cell division (cytokinesis) either alone or in conjugation with auxin.

**Discovery** : The first cytokinin was discovered by Miller, Skoog and Strong (1955) during callus tissue culture of *Nicotiana tabacum* (tobacco).

It was synthetic product formed by autoclaving Herring sperm (fish sperm) DNA. This synthetic product was identified as 6-furfuryl amino-purine and named as kinetin. He found that normal cell division induced by adding yeast extract.

Various terms such as kinetenoid (Burstran, 1961), phytokinin (Dendolph *et al.* 1963) phytocytomine (Pilet 1965) have been used for kinetin like substances but the term cytokinin proposed by Letham (1963) has been widely accepted. Letham *et al.* (1964) discovered first natural, cytokinin in unripe maize grain (*Zea mays*). It was named as zeatin (6 hydroxy 3 methyl trans 2-butenyl amino purine).

About 18 cytokinins have been discovered, e.g., dihydrozeatin, IPA (Isopentenyl adenine), benzyl adenine. The most widely occurring cytokinin in plant is IPA. It has been isolated from *Pseudomonas tumefaciens*. Many are found as constituents of tRNAs. Cytokinins are synthesized in roots as well as endosperm of seeds. Coconut milk and Apple fruit extract are rich in cytokinins. Cytokinins in coconut milk are called coconut milk factor.

Kinetin (6 furfuryl amino purine) is a derivative of the nitrogen base adenine. Cytokinins are produced in actively growing tissues such as embryos, developing fruits and roots.

Cytokinin is transported to different parts of the plant through xylem elements.

According to Osborne and Black (1964), the movement of cytokinin is polar and basipetal.

**Bioassay of cytokinins** : Bioassay is done through retention of chlorophyll by leaf discs, gains of weight of a tissue in culture, excised radish cotyledon expansion, root inhibition test etc.

#### Functions of cytokinins

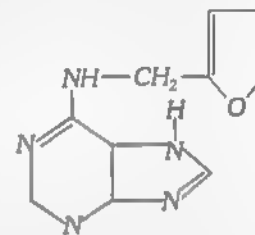
(1) **Cell division** : Cytokinins are essential for cytokinesis and thus promote cell division. In presence of auxin, cytokinins stimulate cell division even in non-meristematic tissues. In tissue cultures, cell division of callus (undifferentiated mass of parenchyma tissue) is enhanced when both auxin and cytokinin are present. But no response occurs with auxin or cytokinin alone.

(2) **Cell enlargement and Differentiation** : Under some conditions cytokinins enhance the expansion of leaf cells in leaf discs and cotyledons. These cells considered to be mature and under normal conditions do not expand. Cytokinins play a vital role in morphogenesis and differentiation in plants. It is now known that kinetin-auxin interaction control the morphogenetic differentiation of shoot and root meristems

(3) **Delay in senescence** : Cytokinin delay the senescence (ageing) of leaves and other organs by controlling protein synthesis and mobilization of resources (Disappearance of chlorophyll). It is called Richmond Lang effect. It was reported by Richmond and Lang (1957) while working on detached leaves of *Xanthium*.

(4) **Counteraction of apical dominance** : Auxins and cytokinins act antagonistically in the control of apical dominance. Auxins are responsible for stimulating growth of apical bud. On the other hand, cytokinins promote the growth of lateral buds. Thus exogenous application of cytokinin has been found to counteract the usual dominance of apical buds.

(5) **Breaking of dormancy** : Cytokinins break seeds dormancy of various types and thus help in their germination. They also induce germination of positively photoplastic seed like lettuce and tobacco even in darkness



Kinetin (6-furfuryl aminopurine)



(6) **Accumulation and Translocation of solutes :** Cytokinins induce accumulation of salts inside the cells. They also help solute translocation in phloem.

(7) **Sex expression :** Cytokinins promote formation of female flowers in some plants.

(8) **Enzyme activity :** Cytokinins stimulate the activity of enzymes especially those concerned with photosynthesis.

(9) **Parthenocarpy :** Development of parthenocarpic fruits through cytokinin treatment has been reported by Crane (1965).

(10) **Pomalin :** A combination of cytokinin (6-benzyladenine) and gibberellin ( $GA_4$ ,  $GA_7$ ) called pomalin is particularly effective in increasing apple size.

(11) **Initiation of interfascicular cambium :** Cytokinins induce the formation of interfascicular cambium in plants e.g., *Pinus radiata*.

(12) **Nucleic acid metabolism :** Guttman (1957) found a quick increase in the amount of RNA in the nuclei of onion root after kinetin treatment.

(13) **Protein synthesis :** Osborne (1962) demonstrated the increased rate of protein synthesis on kinetin treatment.

(14) **Short day plants :** Cytokinins promote flowering in some short-day plants like *Lemna* and *Wolffia*.

**Ethylene :** Ethylene is a gaseous hormone which stimulates transverse growth but retards the longitudinal one.

**Discovery :** The effect of ethylene had been known since long. Kerosene lamps and hay have been used by fruit merchants to hasten colour development (ripening) in fruits. These effects are due to ethylene. Neljubow (1901) observed that ethylene gas alters the tropic responses of roots. Denny (1924) reported that ethylene induces ripening of fruits. Crocker *et al.* (1935) identified ethylene as gaseous plant hormone.

Ethylene is produced in plants from the amino acid methionine. It is synthesized in almost all plant parts—roots, leaves, flowers, fruits, seeds. It is more synthesized in nodal regions. Maximum synthesis of ethylene occurs during climacteric ripening of fruits. High concentration of auxin induce ethylene formation. When a fruit ripens, its respiration rate gradually decreases, but when it is reversed by a sharp increase called climacteric. Some of the inhibitory effects earlier attributed to auxin are known to be caused by ethylene.

The commercial product for providing ethylene is ethaphon (2-chloroethyl phosphoric acid). Ethaphon is a liquid from which ethylene gas is released, hence this substance is used for artificial ripening of fruits.

**Bioassay of ethylene :** It is done on the principle of triple response which includes three characteristic effects of ethylene on etiolated seedlings of pea—viz.

- Swelling of nodes.
- Inhibition of elongation of internodes of stem.
- Induction of horizontal growth of stem against gravity.

#### Functions of ethylene

(1) **Fruit growth and Ripening :** Ethylene promotes fruit growth and its ripening. The hormone is used in the artificial ripening of climacteric fruits (e.g., Apple, Banana, Mango)

Suitable combination of gases in atmosphere for fruit ripening is 80% ethylene ( $C_2H_4$ ) and 20%  $CO_2$ .

(2) **Transverse growth :** Ethylene inhibits longitudinal growth but stimulates transverse growth so that stem looks swollen.

(3) **Epinasty (leaf bending) :** Epinasty represents more growth on upper surface of leaf than on lower surface. Epinasty is said to be controlled by ethylene in many plants.

(4) **Abscission :** Ethylene stimulates formation of abscission zone in leaves, flowers and fruits.

(5) **Apical dominance :** Ethylene inhibits the growth of lateral buds and thus cause apical dominance (in pea). It is believed that auxin might be functioning partly through synthesis of ethylene in causing apical dominance.

(6) **Root initiation :** In low concentration, ethylene stimulates root initiation and growth of lateral roots and root hair.

(7) **Flowering :** Ethylene stimulates flowering in pineapple and related plants though in other cases, the hormone causes fading of flowers. Fading flowers of *Vanda* are known to release ethylene. Sleep disease (inrolling of petals in blossomed flowers) is due to ethylene.

(8) **Sex expression :** Ethylene application increases the number of female flowers and fruits in cucumber plants.

(9) **Dormancy :** It breaks dormancy of different plant organs but not of lateral buds.

**Abscisic acid (ABA) :** Absciscic acid is a mildly acidic growth hormone, which functions as a general growth inhibitor by counteracting other hormones (auxin, gibberellins, cytokinins) or reactions mediated by them.

**Discovery :** The hormone was first isolated by Addicott *et al.* (1963) from cotton balls. They named it as abscisin II. Simultaneously, Wareing and Comforth isolated a substance that can induce bud dormancy. They named the substance as dominin. Later, both these substances were found to be the same and were named as abscisic acid. It is produced in many parts of the plants but more abundantly inside the chloroplasts of green cells. The synthesis of abscisic acid is stimulated by drought, water logging and other adverse environmental conditions. Therefore, it is also called stress hormone. The hormone is formed from mevalonic acid or xanthophylls. Chemically it is dextro-rotatory cis sesquiterpene. The hormone is transported to all parts of the plant through diffusion as well as through conductive channels.

In some plant tissues (especially in young shoots) occur a related compound called xanthoxine.

Whether xanthoxine is an intermediate of the ABA-biosynthesis or whether it is an independent product remains unknown. The structure indicates that both ABA and xanthoxine are terpene derivatives.

#### Bioassay of abscisic acid

(1) **Rice seedling growth inhibition test :** Mohanty, Anjaneyulu and Sridhar (1979) used rice growth inhibition method to measure ABA like activity. The length of second leaf sheath after six days of growth is measured

**2) Inhibition of  $\alpha$ -amylase synthesis in barley endosperm test :** ABA inhibits the synthesis of  $\alpha$ -amylase in the aleurone layers which is triggered by gibberellins. Goldschmidt and Monselise (1968) developed the bioassay method to estimate ABA activity by determining the extent of inhibition of  $\alpha$ -amylase synthesis induced by treating barley seed endosperm with GA.

#### Functions of abscisic acid

(1) **Control :** It keeps growth under check by counteracting the effect of growth promoting hormones, i.e., auxins, cytokinins and gibberellins. As growth is primarily controlled by gibberellins, abscisic acid is popularly called antigibberellic hormone. It will inhibit seed germination, growth of excised embryos, growth of Duckweed and other plants.

(2) **Dormancy :** Absciscic acid acts as growth inhibitor and induces dormancy of buds towards the approach of winter. Dormancy of seeds is mainly caused by abscisic acid. Because of its action in inducing dormancy abscisic acid (ABA) is also called dormin. The buds as well as seeds sprout only when abscisic acid is overcome by gibberellins.

(3) **Abcission :** ABA promotes the abscission of leaves, flowers and fruits in plants.

(4) **Senescence :** Absciscic acid stimulates senescence of leaves by causing destruction of chlorophyll (an effect opposite to that of cytokinins) and inhibition of protein and RNA synthesis. The effect, however, can be reversed by application of cytokinins in *Lemna*.

(5) **Antitranspirant :** Absciscic acid can be used as antitranspirant. Application of minute quantity of ABA to leaves reduces transpiration to a great extent through partial closure of stomata. It thus conserves water and reduces the requirement of irrigation.

(6) **Hardiness :** Absciscic acid promotes cold hardiness and inhibits growth of pathogens.

(7) **Flowering :** ABA delays flowering in long day plants. However, in some short day plants (e.g., strawberry, black current) it promotes flowering.

(8) **Rooting :** Absciscic acid can be used to promote rooting in many stem cuttings.

**Wound hormone or Traumatic acid or Necrohormone :** Haberlandt (1913) reported that injured plants cells release a chemical substance (wound hormone), which stimulate the adjacent cells to divide rapidly in order to heal up the wound. English et al. (1939) finally isolated and crystallized this wound hormone and named it as Traumatic acid. Although traumatic acid has been found to be very active in inducing meristematic activity in uninjured green bean pods, but it is not effective in most of the plant tissues including tobacco pith tissues.

**Morphactins :** Morphactins are synthetic growth regulators which act in variety of ways on the natural regulation mechanisms of plants. The important ones are phenoxyalkanoic acid (synthetic auxin), substituted benzoic acids, Malic acid hydrazide, Fluorene-9 carboxylic acids and their derivatives, Chloroflurenol, Chloroflurun, Flurenol, Methylbenzilate, Dichloroflurenol, etc. Morphactins have fundamental action on morphogenesis of plants and this characteristic designation (morphactins) is derived from morphologically active substances.

The actions of these substances are systematic and after their uptake they are transported and distributed not polarly (as seen by IAA) but basi- and acropetally. Generally these are growth inhibitors. These contain 'fluorene ring' in their structure.

#### Functions

(1) **Seed germination :** In general, morphactins inhibit seeds germination particularly the emergence of the radicle from the seed shell. This property can be counteracted with GA<sub>3</sub> and almost completely by cytokinins. The germination of fern spores is also delayed by morphactins.

(2) **Growth seedling :** Morphactins inhibit the growth of seedling affecting the shoot and often also root. With this property they show a similarity with cytokinin. The inhibitory effect of seedling shoot growth can be partly counteracted with GA<sub>3</sub> but not the inhibition of root growth.

(3) **Stem elongation :** They have inhibitory effect on the stem elongation. Increased concentration produces dwarfing in the plants.

(4) **Polarity of cell division :** Denffer and others (1969) observed in the dividing cells of the root tips of *Allium* that treatment of morphactin (CFI) results in random orientation of the mitotic spindle and plane of cell division, i.e., they exercise depolarisation during cell division.

**Jasmonic acid (Jasmonates) :** According to Parthier (1991), jasmonic acid and its methyl esters are ubiquitous in plants. They have hormone properties, help regulating plant growth, development and they seem to participate in leaf senescence and in the defense mechanism against fungi

Just like ABA jasmonates inhibit a premature germination of the oil-containing seeds of *Brassica* and *Linum*. After germination they induce the synthesis of the seed storage proteins Napin and Cruciferin as well as that of several more elaiosome-associated proteins.

**Calines (Formative hormones) :** Certain other natural growth hormones in plants called as calines or formative hormone which are through to be essential for the effect of auxin on root, stem and leaf growth they are :

(1) **Rhizocaline or Root forming hormone :** It is produced by the leaves and translocated in a polar manner down the stem.

(2) **Caulocaline or Stem forming hormone :** It is produced by the roots and is transported upward in the stem.

(3) **Phyllocaline or Self forming hormone :** It is produced probably by the cotyledons. It stimulates mesophyll development in the leaves and is synthesized only in the presence of light.

#### Physiology of flowering plant

Flowering in a plant occurs at a particular time of the year and controlled by many morphological and environmental conditions. Two important controlling factors are photoperiod or light period, i.e., photoperiodism, low temperature i.e., vernalization.

(1) **Photoperiodism (Light period) :** The effects of photoperiods or daily duration of light periods (and dark periods) on the growth and development of plants, especially flowering is called photoperiodism.

The role of photoperiodism in the control of flowering was demonstrated for the first time by W.W. Garner and H.A. Allard (1920). They observed that Maryland mammoth variety of tobacco could be made to flower in summer by reducing the light hours with artificial darkening. It could be made to remain vegetative in winter by providing extra light. On the basis of length of photoperiod requirements of plants, the plants have been classified into following categories.

(i) **Short day plants (SDP)** : These plants initiate flowering when the day length (Photoperiod) become shorter than a certain critical period. Most of winter flowering plants belong to this category e.g., cocklebur (*Xanthium*), *Chrysanthemum*, sugarcane, tobacco (Mutant Maryland mammoth), soybean, strawberry, *Dahlia* etc.

(ii) **Long day plants (LDP)** : These plants begin flowering when the day length exceeds a critical length. This length too differs from species to species. The long day plants fail to flower, if the day length is shorter than the critical period. e.g., spinach (*Spinacea oleracea*), henbane (*Hyoscymus niger*), radish, sugarbeet, wheat, lettuce, poppy, larkspur, maize etc.

(iii) **Day neutral plants** : These plants can flower in all possible photoperiods. The day neutral plants can blossom throughout the year. e.g., cucumber, cotton, sunflower, tomato, some varieties of pea, etc.

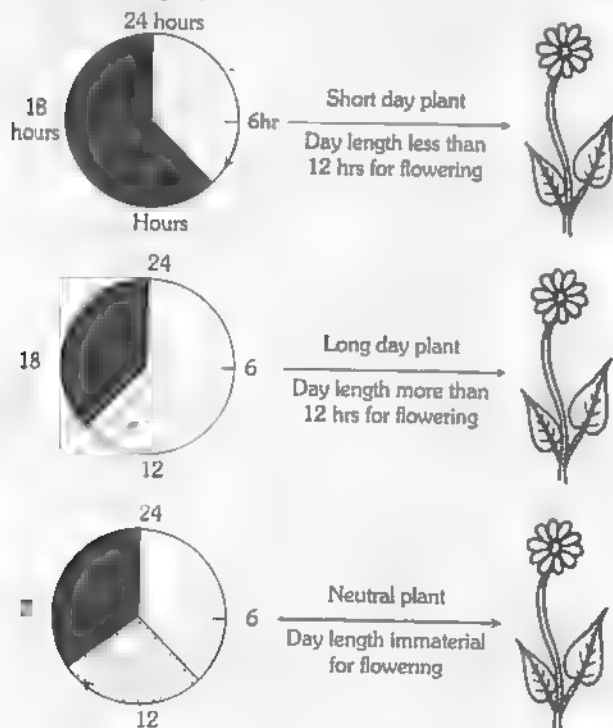


Fig : 4.5-3 The day-length requirements for flowering in three categories of plants

(iv) **Intermediate plants** : These plants flower only under day lengths within a certain range usually between 12-16 hours of light but fail to flower under either longer or shorter photoperiods. e.g., *Mikania scandens*, *Eupatorium hyssopifolium* and *Phaseolous polystacous*.

(a) **Amphiphotoperiodic plants** : Such plants remain vegetative on intermediate days length and flower only on shorter or longer day lengths. e.g., *Media elegans*.

(b) **Short long day plants** : These plants require short photoperiods for initiation of flowering and long photoperiods for blossoming. e.g., *Triticum vulgare*, *Secale cereale*.

(c) **Long short day plants** : These plants require long photoperiods for initiation of flowering and short photoperiods for blossoming. e.g., *Bryophyllum*, *Cestrum*.

**Critical period** : Critical photoperiod is that continuous duration of light, which must not be exceeded in short day plants and should always be exceeded in long days plant in order to bring them to flower. There is no relation with the total day length. Thus, the real distinction between a SDP and LDP is whether flowering is induced by photoperiods shorter or longer than the critical period. The critical day length for *Xanthium* (a short day plant) is 5 – 6 hours and that for *Hyoscymus niger* (a long day plant) is about 11 hours, yet the former is SDP as it flowers in photoperiods shorter than its critical value, whereas the latter is LDP requiring photoperiods longer than its critical value. Both *Xanthium* and *Hyoscymus niger* flower with 14 hours of light per day. Thus, day length in which a plant flowers is no indication of its response class in the absence of further information.

**Skotoperiodism (Dark period)** : When photoperiodism was discovered, the duration of the light period was thought to be critical for flowering. Subsequently, it was found that when the long night period was interrupted by a brief exposure to light, the short day plants, failed to flower. Thus, for flowering, these plants require a long night or critical dark period rather than a short day length. Similarly, long day plants respond to nights shorter than the critical dark period. Curiously, they do not need an uninterrupted dark period. Therefore, a short day plant is also called long night plant and a long day plant as a short night plant

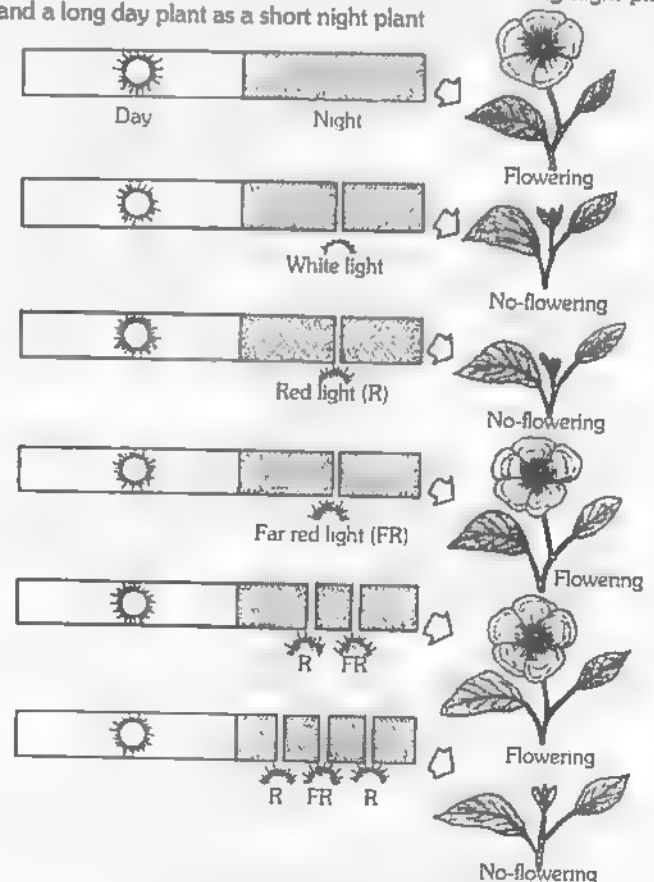


Fig : 4.5-4 Effect of night (Dark) interruption on flowering in a short-day plant

In the night interruption experiments, when the short day plants were exposed to a flash of light before achieving a critical dark period, flowering was prevented. It is called light break reaction.

#### Mechanism of photoperiodism

**Photoreceptor** : The chemical which perceives the photoperiodic stimulus in leaves is phytochrome. The wavelengths of light are absorbed by the leaves. This becomes evident by the fact that defoliated (leaves removed) plant does not flower. Presence of even a single leaf is sufficient to receive required amount of photoperiod. Partially mature leaves are more sensitive to light while very young or mature leaves are much less sensitive to photoperiodic induction.

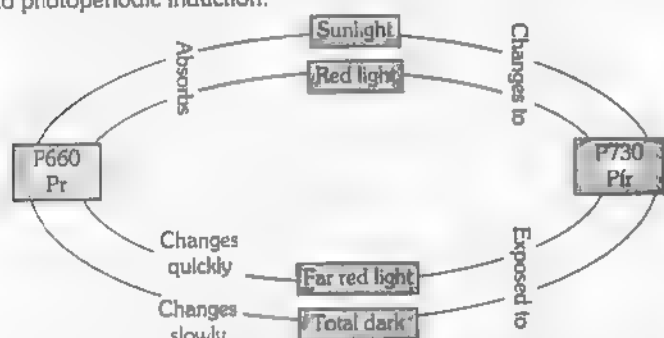


Fig : 4.5-5 The phytochrome concept

Garner and Allard's early work led to the discovery, isolation and much of the characterization of the pigment responsible for absorbing light involved in photoperiodic phenomenon of plants. Borthwick, Hendricks and their colleagues later termed this pigment phytochrome. Pigment was isolated by Butler *et al.* (1959). This pigment controls several light dependent developmental processes in plants besides flowering. Phytochrome exist in two interconvertible forms. The red (660nm), absorbing form Pr and the far red (730 nm), absorbing form Pfr. Pr is converted to Pfr on absorbing red light. Pfr is converted to Pr rapidly absorbing far red light or slowly in darkness. The slow conversion to red absorbing form is under thermal control. During the day when white light available, Pfr accumulates in the plant. This form of phytochrome is inhibitory to flowering in short day plants and stimulatory to flowering in long day plants. In evening, Pfr undergoes thermal and spontaneous decay to change into Pr. This pigment is stimulatory to flowering in short day plants and inhibitory to flowering in long day plants.

Therefore, in SDP interruption of dark periods with a flash of red light converts Pr into Pfr and flowering is inhibited.

**Importance of phytochrome** : Phytochrome is located in plasmamembrane. Phytochrome far red (Pfr) form is considered to be biologically active form and is responsible to initiate a number of physiological process such as.

- (1) Elongation of stem and leaves.
- (2) Plastids morphology and differentiation of stomata.
- (3) Seed germination.
- (4) Photoperiodism and transpiration.

**The florigen complex (Flowering hormone)**: When the proper amount of light is perceived by leaves, they produce a chemical (flowering hormone), which undergoes stabilisation in dark. Later on, this chemical passes to shoot apex and causes its differentiation into flowering shoot.

Chailakhyan (1936) a Russian investigator on photoperiodism, proposed that it be called 'florigen'. According to him (1958) the "Florigen complex", the true flowering hormone includes two groups of substances formed in leaves :

**Gibberellins** : Which are necessary for formation and growth of stem.

**Anthesins** : Substances which are necessary for flower formation.

**Photomorphogenesis** : When plants are grown in continuous darkness they become etiolated i.e., such plants are longer, weaker, having yellowish half opened leaves, while light grown plants do not show such conditions. When etiolated plants are kept in light they gradually develop green colour and become normal. The effect of light in reversing etiolation involves two kinds of action; one at the biochemical level for the synthesis of the chlorophyll and secondly at the level of morphogenesis light acts to promote expansion of the leaves and inhibits elongation of the internodes. This phenomenon is called photomorphogenesis and is independent of the direction of light.

The action spectrum of photomorphogenesis reveals that plants are most sensitive to red light, but blue light is ineffective.

(2) **Vernalization** : Russian agronomist Lysenko coined the term vernalization (1929-30). According to him vernalization may be defined as the method of inducing early flowering in plants by pretreatment of their seeds at low temperatures. Chourad (1960) has defined it as the acquisition or acceleration of the ability to flower by chilling treatment. The low temperature requirement for flowering was first noticed by Klippert (1857) while working with winter varieties of cereals such as wheat, barley, oat and rye. He observed that, these varieties when sown in spring failed to flower the same year but grow vegetatively. Such winter varieties, when sown in the autumn, they flowered in spring of the same year.

**Site of vernalization** : The stimulus of vernalization is perceived only by the meristematic cells such as shoot tip, embryo tips, root apex, developing leaves etc.

#### Requirement of vernalization :

(i) **Low temperature** : Low temperature required for vernalization is usually 0-4°C is most of the cases. The chilling treatment should not be immediately followed by high temperature (i.e., about 40°C), otherwise the effect of vernalization is lost. This phenomenon is called de-vernalization.

(ii) **Duration of low temperature treatment** : It varies from species to species from a few hours to a few days.

(iii) **Actively dividing cells** : Vernalization stimulus is perceived only by actively dividing cells. Therefore, vernalization treatment can be given to the germinating seeds or whole plant with meristematic tissues and other conditions.

(iv) **Water** : Proper hydration is must for perceiving the stimulus of vernalization

(v) **Oxygen** : Aerobic respiration is also a requirement for vernalization. The stimulus has been named as vernalin (reported by Mechlers).

**Process of vernalization** : Usually vernalization treatment is given to the germinating seeds. The seeds are moistened sufficiently to allow their germination. They are then exposed to a temperature of 0-4°C for a few weeks and sown to the fields. Lysenko developed the process of vernalization. It is completed in two stages.

(i) **Thermostage** : Germinating seeds are treated with 0-5°C in presence of oxygen and slight moisture. The seed dormancy is broken.

(ii) **Photostage** : This stage is very essential to initiate the reproductive phase. After vernalization plants must be subjected to a correct photoperiod in order that they may produce flowers.

#### Importance of vernalization

(i) Vernalization is believed to overcome some inhibitor and induce synthesis of growth hormones like gibberellins.

(ii) It reduces the vegetative period of plant.

(iii) It prepares the plant for flowering.

(iv) It increases yield, resistance to cold and diseases.

(v) Vernalization can remove kernel wrinkles in wheat.

(vi) Vernalization is beneficial in reducing the period between germination and flowering. Thus more than one crop can be obtained during a year.

### Senescence and Death

Plant and their parts develop continuously from germination until death. The production of flowers, fruits and seeds in annuals and biennials leads to senescence. The latter part of the developmental process, which leads from maturity to the ultimate complete loss of organization and function is termed senescence. Several workers equate ageing and senescence as same process. Ageing is a sum total of changes in the total plant or its constituents while senescence represents degenerative and irreversible changes in a plant. The study of plant senescence is called phytoogerontology.

**Types of senescence** : Plant senescence is of four types- whole plant senescence, shoot senescence, sequential senescence and simultaneous senescence. The last three are also called organ senescence

(1) **Whole plant senescence** : It is found in monocarpic plants which flower and fruit only once in their life cycle. The plants may be annual (e.g., rice, wheat, gram, mustard etc.), biennials (e.g., cabbage, henbane) or perennials (e.g., certain bamboos). The plant dies soon after ripening of seeds.

(2) **Shoot senescence** : This type of senescence is found in certain perennial plants which possess underground perennating structures like rhizomes, bulbs, corm etc. The above ground part of the shoot dies each year after flowering and fruiting, but the underground part (stem and root) survives and puts out new shoots again next year. e.g., banana, gladiolus, ginger etc.

(3) **Sequential senescence** : This is found in many perennial plants in which the tips of main shoot and branches remain in a meristematic state and continue to produce new buds and leaves. The older leaves and lateral organs like branches show senescence and die. Sequential senescence is apparent in evergreen plants e.g., *Eucalyptus*, *Pinus*, *Mango*.

(4) **Simultaneous or synchronous senescence** : It is found in temperate deciduous trees such as elm and maple. These plants shed all their leaves in autumn and develop new leaves in spring. Because of this shedding of leaves, autumn season is also called fall. e.g., *Dalbergia*, *Elm*, *Mulberry*, *Poplar*.

#### Theories of senescence

(1) **Wear and tear** : According to this theory, senescence occurs due to loss of activity and cells undergo wear and tear due to disintegration of organelles.

(2) **Toxicity** : It is viewed that senescence takes place due to accumulation of toxic and deleterious substances in all.

(3) **Loss of metabolites** : It is assumed that senescence leads to gradual depletion of essential metabolites in a cell.

(4) **Genetic damage**

#### Characteristics of ageing and senescence

(1) There is general decline in metabolic activities, decline in ATP synthesis and also decreased potency of chloroplast.

(2) Decrease in RNA and DNA.

(3) Decrease in semipermeability of cytoplasmic membranes.

(4) Decrease in the capacity to repair and replace wornout cells.

(5) There may be accumulation of chromosomal aberrations and gene mutations with advancing age. As a result of these changes protein synthesis becomes defective.

(6) Increased production of hydrolytic enzymes such as proteases and nucleases.

(7) Deteriorative change in cell organelles and membranes.

(8) Decrease in the internal content of auxin and cytokinins and increase in the production of abscisic acid or ethylene.

**Importance of senescence** : Biologically, senescence and death have following advantages :

(1) It maintains efficiency since the old and inefficient organs are replaced by young efficient part like leaves, buds, flowers and fruits. etc.

(2) During senescence, the cellular breakdown results in release of many nutrients including amino acids, amides, nucleotides, simple sugars and minerals. The same are withdrawn from the senescing organs into the main trunk and later utilised in the growth and developed of new parts.

(3) Shoot senescence is a mechanism to help the plants perennate during the unfavourable periods.

(4) Simultaneous or synchronous leaf fall occurs in autumn prior to winter. It reduces transpiration, which is essential for survival in winter, when the soil is frozen and roots can not absorb water.

(5) Litter of fallen leaves and twigs is an important source of humus and mineral replenishment for the soil.

### Abscission

The process of shedding of leaves, fruits or flowers by a plant is called abscission. The shedding of plant parts takes place by the formation of a special layer of cells called abscission layer, within the region of attachment. The middle lamella between certain cells in this layer is often digested by polysaccharide hydrolyzing enzymes such as cellulase and pectinases.

## Tips & Tricks

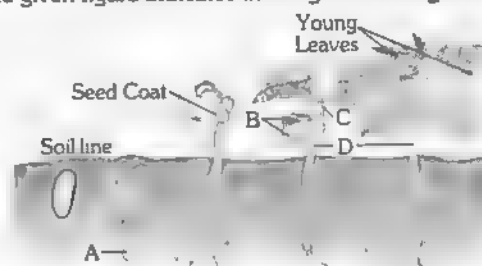
- ✎ The double sigmoid growth curve occurs in some fruits e.g., Grapes, plum.
- ✎ Measurement of growth in young root by making it at 1mm intervals with Indian Ink was first done by Strasburger
- ✎ The development of shoot and root is determined by cytokinin and auxin ratio.
- ✎ Mixture of 2, 4-D and 2, 4, 5-T (dioxin) is given the name 'Agent orange' which was used by USA in Vietnam war for defoliation of forests (i.e., in chemical warfare).
- ✎ In glass houses when plants are kept on artificial light and temperature, then this method is called phytotron and is applicable in agriculture, horticulture and tissue culture.
- ✎ Phytotron is a method in which plants are grown in controlled environment
- ✎ When each meristem influences other meristems then this phenomenon is called growth correction.
- ✎ ABA is used in dryfarming
- ✎ Malic hydrazide is a growth retardant which checks cell division. So during seed storage this is applied for checking sprouting of potato tubers so that the importance of potato may be lowered down.
- ✎ Auxin and Cytokinin in combined form shows synergistic effect (affects development of physical structure).
- ✎ SDP's contain anthesins and synthesize gibberellic acid for flowering. Whereas LDP's contain GA and synthesize anthesins for flowering.
- ✎ Leaves show maximum expansion in violet light.
- ✎ Knott (1934) found that the locus of photoperiodic induction is the leaves.
- ✎ Wellensick (1964) found that the locus for perception of cold treatment is the meristematic cells (at all places) especially the shoot apex.
- ✎ Reduced availability of auxin stimulates leaf fall while presence of auxin slows down leaf fall. Cytokinin prevent senescence through stimulating anabolic activity. They are called antiageing hormones Florigen hormone synthesized in the leaves.
- ✎ Geotropic stimulus is perceived by root cap in case of root by stem apex in case of stem.

## Ordinary Thinking

### Objective Questions

#### Growth

2. The given figure indicates the stages of seed germination



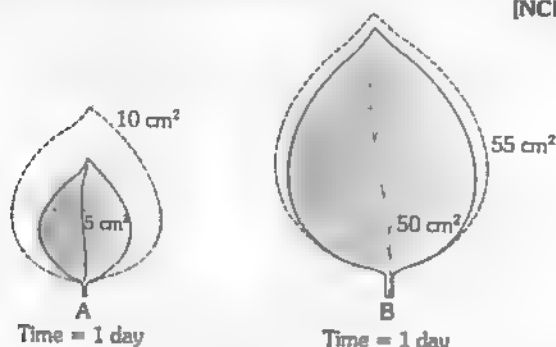
Identify A, B, C and D respectively

[NCERT]

- (a) Root hair, Cotyledons, Epicotyl and Hypocotyl
  - (b) Mesocotyl, Cotyledons, Epicotyl and Hypocotyl
  - (c) Radicle, Cotyledons, Epicotyl and Hypocotyl
  - (d) Plumule, Cotyledons, Epicotyl and Hypocotyl
3. Which of the following instrument can be used to record plant growth by seconds i.e. in fraction of a minute
- (a) Arc auxanometer
  - (b) Arc indicator
  - (c) Space marker disc
  - (d) Crescograph
4. Which two factors primarily affect the developmental phase of growth of plants
- (a) Light and temperature
  - (b) Rainfall and temperature
  - (c) Light and wind
  - (d) Temperature and relative humidity
5. Evergreen trees remain green throughout the year on account of
- (a) Absence of leaf fall
  - (b) Leaves falling in small numbers at intervals
  - (c) Supply of the moisture throughout the year
  - (d) Cold climate
6. The growth involves
- (a) Cell division
  - (b) Cell enlargement
  - (c) Cell maturation
  - (d) All the above
7. Where would you look for active cell division in plants
- (a) In the pith cells
  - (b) In the cells of cortex
  - (c) In the intermodal region
  - (d) At the tip of root and shoot
8. Plant growth in length is increased by
- [MP PMT 1998]
- (a) Apical meristem
  - (b) Lateral meristem
  - (c) Dermatogen
  - (d) Periblem
9. Growth is
- (a) Unidirectional backward
  - (b) Reversible
  - (c) Unidirectional forward
  - (d) None of the above
10. Phytotron is a device by which
- [CPMT 1995; AIIMS 1998; MH CET 2001]
- (a) Electrons are bombarded
  - (b) Protons are liberated
  - (c) Plants are grown in controlled environment
  - (d) Mutation are produced in plants
11. The S-shaped growth curve and 'grand period of growth' may change with
- (a) Sudden fluctuation in light intensity
  - (b) Change in temperature
  - (c) Fluctuation in humidity
  - (d) It remains unaffected

12. See the figure and choose the correct option from table

[NCERT]



	A - Leaf		B - Leaf	
	AGR	RGR	AGR	RGR
(a)	0.5	100%	1.5	100%
(b)	5	100%	5	10%
(c)	100%	5	10%	5
(d)	1%	1	2%	2

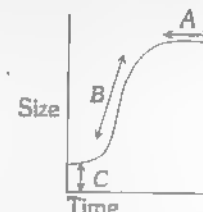
13. Deeply sown seeds do not germinate and do not come up over due to the deficiency of  
 (a) Light (b) Water  
 (c) Oxygen (d) Nutrients
14. The rate of growth of any organism follows [MP PMT 1998]  
 Or  
 Typical growth curve in plants is [AIPMT (Cancelled) 2015]  
 (a) Hyperbola curve (b) J-shaped curve  
 (c) Sigmoid curve (d) Parabola curve
15. Exponential growth occurs in [Odisha JEE 2009]  
 (a) Yeast (b) Asexual reproduction  
 (c) Bacterial (d) All of these
16. Dendrochronology is [Kerala CET 2003]  
 (a) Secondary growth  
 (b) Apical growth  
 (c) Seasonal variation  
 (d) Determination of age of tree
17. In vascular plants, light promotes  
 (a) Growth (b) Development  
 (c) Differentiation (d) De-differentiation
18. In lag phase, the growth is  
 (a) Slowest (b) Fastest  
 (c) Intermediate (d) No growth at all
19. To remove seed dormancy by mechanical removing of seed coat is called [DPMT 2003; J & K CET 2008]  
 (a) Stratification (b) Scarification  
 (c) Vernalization (d) Photoperiodism
20. Highest growth is found in [NCERT; Pb. PMT 1999; RPMT 1999; CBSE PMT 2004]  
 (a) Static phase (b) Exponential phase  
 (c) Descending phase (d) Lag phase
21. The growth in plants is [MP PMT 1999]  
 (a) Limited (b) Unlimited  
 (c) Unlocalised (d) None of these

22. Which of the following is the primary motive force responsible for growth

(a) Root pressure (b) Turgor pressure  
 (c) Osmotic pressure (d) DPD

23. Given below is a graph drawn on the parameters of growth versus time A, B, C respectively represent

[NCERT; Kerala PMT 2007; AIIMS 2011]



- (a) Exponential phase, log phase and steady state phase  
 (b) Steady state phase, log phase and lag phase  
 (c) Slow growing phase, lag phase and steady state phase  
 (d) Lag phase, steady state phase and logarithmic phase  
 (e) Lag phase, log phase and steady state phase
24. "Traumatm" is present in  
 (a) Old leaves (b) Cork  
 (c) Wood (d) Injured portion
25. Seeds of parasitic plants like *Orobanch* germinate in the presence of  
 (a) Auxin produced by the roots of the host  
 (b) GA<sub>3</sub> produced by the roots of the parasite  
 (c) Exudates of the host plant  
 (d) Exudates of the parasite
26. Growth is maximum in the zone of [AFMC 1994]  
 (a) Cell division (b) Cell elongation  
 (c) Cell maturation (d) All of these
27. The instrument by which the rate of growth of stem is accurately measured is [CPMT 1995, 2002; Kerala CET 2003; J & K CET 2005; Odisha JEE 2012]  
 Or  
 Growth in length of a plant can be measured by [Pb. PMT 2004; AMU (Med) 2005; RPMT 2005; HP PMT 2005; AFMC 2010]  
 (a) Hydrometer (b) Auxanometer  
 (c) Osmometer (d) Potometer
28. Several horticultural techniques are followed for the production of 'bonsai' plants. One of them is drastic pruning of root system. Which of the following physiological factor is involved in that method [CBSE PMT 1990]  
 (a) Inadequacy of mineral nutrients  
 (b) Deficiency of auxins  
 (c) Impairment of water absorption  
 (d) Deficiency of cytokinins
29. Distribution of growth in a root by marking it at equal intervals with Indian ink was originally studied by  
 (a) Wellensick (b) Strasburger  
 (c) Went (d) Nitsch
30. Classical experiments on growth were performed by  
 (a) Lamarck and Boysen-Jennsen  
 (b) Boysen-Jennsen and Darwin  
 (c) Darwin and Lamarck  
 (d) De Vries and Paul
31. The type of growth of bands in conifers is  
 (a) Lateral (b) Delinquent  
 (c) Caudex (d) Excurrent



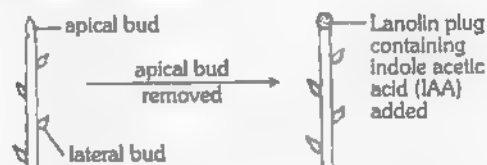
## Growth Hormones

- Among plants 'pheromones' are secreted by the cells of following plants for the given function [BHU 1994]
  - All plants for growth and development
  - Yeast for facilitating mating
  - All fungi for sexual reproduction
  - Rhizopus* for the formation of zygospore
- The natural plant hormones were first isolated from
  - Corn germ oil and human urine
  - Cotton fruits, spinach leaves and rice plants
  - Avena coleoptile spinach leaves and the fungus gibberella
  - Human urine and rice seedlings
- Who used the term 'phytohormones' for plant hormone
  - Balis
  - Morgan
  - Went
  - Thimann
- Phytohormones control [CBSE PMT 1990]
  - Growth
  - Physiological functions
  - Rooting
  - Flowering
- Legume seeds exhibit dormancy because of
  - Undeveloped embryo
  - Hard seed coat
  - Absence of cytokinin
  - Absence of  $GA_3$
- By hormone application it is possible to obtain seedless fruits. In which of the following it is undesirable to obtain seedless fruits
  - Tomato
  - Orange
  - Watermelon
  - Pomegranate (Anar)
- In which of the following respect, the plant hormones differ from enzymes [BVP 2003]
  - Required in less quantity
  - They are expended in the process
  - They release some energy
  - None of the above
- Plant hormones are usually
  - Proteins
  - Lipids
  - Carbohydrates
  - Aromatic compounds
- Whose technique is employed for the extraction and elimination of hormones
  - Beck
  - Beer
  - Garner
  - Allard
- Who for the first time speculated the presence of organ forming substances in plant now called hormones [MP PMT 2001]
  - Darwin
  - Went
  - Yabuta
  - Sachs
- Rhizocalin is a additional hormonal substance which is secreted by
  - Cotyledons
  - Roots
  - Leaves
  - Stem
- Certain chemical substances having profound effect on growth, are called [MP PMT 1997]
  - Catalytic agents
  - Phytohormones
  - Enzymes
  - Compost

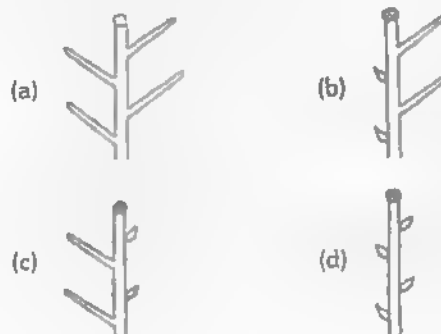
- The pineapple which under natural conditions is difficult to blossom has been made to produce fruits throughout the year by application of [NEET (Karnataka) 2013]
  - NAA, 2, 4-D
  - Phenyl acetic acid
  - Cytokinin
  - IAA, IBA
- To induce formation of organs in a callus it is necessary to provide [MHCET 2015]
  - Growth hormones
  - Water
  - Soil
  - Antibiotics

## Auxin

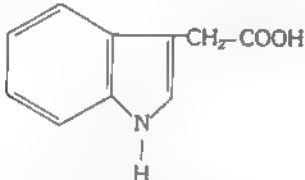
- Leaf fall occurs as abscission layer is formed when the content of [MP PMT 1996]
  - Auxin increases
  - Auxin decreases
  - Abscissic acid decreases
  - Gibberellic acid decreases
- Dr. F. Went noted that if coleoptile tips were removed and placed on agar for one hour, the agar would produce a bending when placed on one side of freshly cut coleoptile stumps. Of what significance is this experiment [CBSE PMT 2014]
  - It supports the hypothesis that IAA is auxin
  - It demonstrated polar movement of auxins
  - It made possible the isolation and exact identification of auxin
  - It is the basis for quantitative determination of small amounts of growth-promoting substances
- Apical dominance in higher plants is due to [NCERT]
  - Balance between auxin and cytokinin
  - Enzyme activity and metabolism
  - Carbohydrates
  - Photoperiodism
- See the following diagram



After two weeks the appearance of the shoot would be [NCERT]





5. Which one of the following plant function is not generally governed or controlled by auxin [AMU (Med.) 2010]  
 (a) Apical dominance (b) Phototropism  
 (c) Photosynthesis (d) Growth
6. Which of the following movements is not related to change in auxin levels [CBSE PMT 1990]  
 (a) Nyctinastic leaf movement  
 (b) Movement of roots towards soil  
 (c) Movement of sunflower tracking the direction of the sun  
 (d) Movement of shoot towards light
7. Parthenocarpy is induced by [KCET 1994]  
 (a) ABA (b) Auxins  
 (c) Zeatin (d) Cytokinin
8. Who among the following discovered the Avena curvature test to find out the concentration of auxins [NCERT]  
 (a) F.W. Went (b) L.J. Audus  
 (c) K.V. Thimman (d) F. Skoog
9. One of the synthetic auxin is [CBSE PMT 2009]  
 Or  
 Flowering in pineapple is promoted by  
 (a) NAA (b) IAA  
 (c) GA (d) IBA
10. Which of the following is not naturally occurring plant hormone [MP PMT 1996; CPMT 1999; JIPMER 2001; BVP 2002; KCET 2009]  
 (a) 2, 4-D (b)  $GA_2$   
 (c) Gibberellin (d) IAA
11. Highest concentration of auxins exist in [CBSE PMT 1990; MP PMT 2000]  
 (a) At the base of various plant organs  
 (b) Growing tip of plants  
 (c) In leaves  
 (d) In xylem and phloem cells only
12. A well known naturally occurring auxin is or A natural growth regulator (hormone) is  
 (a) 2, 4-D (b) Indole acetic acid  
 (c) NAA (d) Maleic hydrazide
13. See the following  
  
 Above structure is of an auxin, that is  
 (a) IAA (b) Auxin b  
 (c) Auxin a (d) None of the above
14. Which one among the following chemical is used for causing defoliation of forest trees [CBSE PMT 1998]  
 (a) Amo-1618 (b) Phosphon-D  
 (c) Maleic hydrazide (d) 2, 4-D
15. Auxins inhibits the growth of  
 (a) Apical bud  
 (b) Lateral axillary buds  
 (c) Roots on stem cuttings  
 (d) Parthenocarpic development of fruits
16. Phototropism in shoots is attributed to [NCERT]  
 (a) Auxin (b) Gibberellins  
 (c) Cytokinins (d) Absciscic acid
17. Differentiation of shoot is controlled by [CBSE PMT 1999]  
 (a) High gibberellin : cytokinin ratio  
 (b) High cytokinin : auxin ratio  
 (c) High auxin : cytokinin ratio  
 (d) High gibberellin : auxin ratio
18. How does pruning help in making the hedge dense [CBSE PMT 2006]  
 (a) The apical shoots grows faster after pruning  
 (b) It releases wound hormones  
 (c) It induces the differentiation of new shoots from the rootstock  
 (d) It frees axillary buds from apical dominance
19. Both in callus and suspension cultures commonly used auxin is [Kerala CET 2005; Odisha JEE 2012]  
 (a) NAA  
 (b) IBA  
 (c) 2, 4-D  
 (d) 2, 4, 5-Trichlorophenoxy acetic acid  
 (e) Absciscic acid
20. Levitt performed experiments. He observed that auxin treated cells were able to absorb water even when kept in hypertonic solution. Which explains this observation best [Manipal 2005]  
 (a) Auxin treated cells lose selective permeability  
 (b) ATP production increases and therefore much energy is available for active absorption  
 (c) Auxin lowers the water potential of cells  
 (d) Auxin increases the solute potential of cells
21. Which of the following ion is pulled out in apoplast by the auxin during growth [CPMT 1999]  
 (a)  $Na^+$  (b)  $K^+$   
 (c)  $Mg^{2+}$  (d)  $H^+$
22. Pruning of plants promotes branching because the axillary buds get sensitized to [AIIMS 2004]  
 (a) Ethylene (b) Gibberellin  
 (c) Cytokinin (d) Indole acetic acid
23. One of the commonly used plant growth hormone in tea plantations is [CBSE PMT (Malna) 2010]  
 (a) Ethylene (b) Absciscic acid  
 (c) Zeatin (d) Indole-3-acetic acid
24. Auxin-B was first isolated by  
 (a) Kogl and Erxleben  
 (b) Kogl, Erxleben and Haagen-Smith  
 (c) Miller and Skoog  
 (d) Yabuta and Sumiki

25. 6-furfuryl amino purine, 2, 4-dichlorophenoxy acetic acid and indole-3-acetic acid are examples respectively for  
[Kerala PMT 2007]  
(a) Synthetic auxin, kinetin and natural auxin  
(b) Gibberellin, natural auxin and kinetin  
(c) Natural auxin, kinetin and synthetic auxin  
(d) Kinetin, synthetic auxin and natural auxin  
(e) Natural auxin, gibberellin and kinetin
26. Apical dominance in plant is caused by [NCERT; BHU 1995, 99; MP PMT 2000; AIEEE Pharmacy 2004; DPMT 2005, 07; J & K CET 2010; Odisha JEE 2010]  
(a) High concentration of auxins in the terminal bud  
(b) High concentration of gibberellins in the apical bud  
(c) High concentration of auxins in the lateral bud  
(d) Absence of auxins and gibberellins in the apical bud
27. Auxin in plant is not meant for [NCERT; BHU 2003]  
Or  
Cell elongation in plants is caused by [CPMT 1994, 95]  
(a) Cell elongation (b) Fruit ripening  
(c) Cell division (d) Inhibit the root growth
28. Synthetic auxins are used for [Kerala CET 2003]  
(a) Killing weeds  
(b) Ripening fruits  
(c) Increasing the size of the fruits  
(d) Stimulating growth of cells in tissue culture
29. Which of the following prevents falling of fruits [KCET 1998; CBSE PMT 2001]  
Or  
Fruit and leaf drop at early stages can be prevented by the application of [NEET 2017]  
(a)  $GA_3$  (b) NAA / Auxin  
(c) Ethylene (d) Zeatin
30. Which of the following is not a physiological effect/an influence of auxin [KCET 2006; Kerala PMT 2012]  
(a) Initiates rooting in stem cuttings  
(b) Promotes flowering  
(c) Prevents fruit and leaf drop at early stages  
(d) Inhibits the growth of lateral buds  
(e) Promotes bolting
31. The substances which have proved very effective to induce rooting from cut end of the stem is [EAMCET 1995; BHU 1999; Pb. PMT 2000]  
Or  
Abscission of fruits is prevented by [Pb. PMT 1999; RPMT 1999]  
(a) Phenyl acetic acid (b)  $\alpha$ -naphthalene acetic acid  
(c) Indole acetic acid (d) Indole butyric acid
32. Auxins originates at the tip of the stem and controls growth elsewhere. The movement of auxin is largely [CBSE PMT 2000; KCET 2007]  
(a) Basipetal (b) Acropetal  
(c) Acropetal and basipetal (d) Centropetal
33. Which of the following effects of auxins on plants is the basis for commercial application  
(a) Callus formation  
(b) Curvature of stem  
(c) Induction of root formation in stem cuttings  
(d) All of the above
34. 2, 4-D is a [CPMT 1996; BHU 2002; Manipal 2005; WB JEE 2016]  
(a) Insecticide (b) Weedicide  
(c) Nematicide (d) Rodenticide
35. During germination, stem grows upward and root goes downward because [CPMT 1995]  
Or  
Phototropic curvature is the result of uneven distribution [CBSE PMT (Pre.) 2010]  
(a) It depends upon light  
(b) Of auxin  
(c) It does not depend on light  
(d) Of epinasty and hyponasty
36. IAA and serotonin are derived (formed) from which of the following [DPMT 2007]  
(a) Tryptophan (b) Tyrosine  
(c) Phenylalanine (d) None of these
37. Bioassay for auxin is [RPMT 1999; BHU 2005; AIPMT 2015]  
(a) Avena curvature test (b) Green leaf test  
(c) Dwarf maize test (d) Cell division test
38. Substances which originate at the tip of the stem and control growth elsewhere are [CPMT 1993]  
(a) Food material (b) Auxins or hormones  
(c) Vitamins (d) Enzymes
39. Avena coleoptile test detects the presence of [RPMT 1999; JIPMER 2002; NEET (Phase-I) 2016]  
(a) IAA (b) GA  
(c) NAA (d) BA
40. Auxins are abundantly produced in [CBSE PMT 1990; BHU 2008]  
(a) Root  
(b) Meristematic region of the root  
(c) Shoot  
(d) Meristematic region of the shoot
41. The presence of auxins in a solution could be tested by [MP PMT 1999]  
(a) Avena sativa stem tip test (b) Carbon tetrachloride test  
(c) Iodine test (d) Defoliation test
42. In plants auxin synthesis occurs in [MP PMT 1994; CPMT 1999; KCET 2000]  
(a) Cortex (b) Phloem cells  
(c) Root and shoot tips (d) Xylem cells
43. You are given a tissue with its potential for differentiation in an artificial culture. Which of the following pairs of hormones would you add to the medium to secure shoots as well as roots [NEET (Phase-II) 2016]  
(a) Gibberellin and abscisic acid  
(b) IAA and gibberellin  
(c) Auxin and cytokinin  
(d) Auxin and abscisic acid

**Gibberellins**

- Gibberellin was first extracted from  
[CPMT 1993, 94, 96, 98, 2003; AFMC 2006]  
(a) *Gibberella fujikuroi* (b) Algae  
(c) Bacteria (d) Roots of higher plants
- Specific property attributed to gibberellins is [KCET 2004]  
(a) Shortening of genetically tall plants  
(b) Elongation of genetically dwarf plant  
(c) Promotion of rooting  
(d) Yellowing of young leaves
- The hormone involved in metabolism of food material in cereal grain during germination is [DPMT 2003; BVP 2004]  
(a) Auxin (b) *CKN*  
(c) GA (d) None of these
- Cell elongation in internodal region takes place due to  
[MP PMT 1999; CBSE PMT 2004; DPMT 2007; J & K CET 2012]  
(a) Gibberellins (b) Ethylene  
(c) Cytokinins (d) Indole acetic acid
- Which of the following plant hormone substitutes for long photoperiods in flowering plants [BHU 2004]  
(a) Auxins (b) Gibberellins  
(c) Cytokinins (d) Ethylene
- Gibberellic acid induces flowering [CBSE PMT 1997]  
(a) In some gymnospermic plants only  
(b) In long day plants under short day conditions  
(c) In short day plants under long day conditions  
(d) In day neutral plants under dark conditions
- Which one of the following pairs, is not correctly matched [CBSE PMT 2007]  
(a) Abscissic acid – Stomatal closure  
(b) Gibberellic acid – Leaf fall  
(c) Cytokinin – Cell division  
(d) IAA – Cell wall elongation
- Parthenocarpic tomato fruites can be produced by  
[CBSE PMT 2006]  
(a) Raising the plants from vernalized seeds  
(b) Treating the plants with phenylmercuric acetate  
(c) Removing androecium of flowers before pollen grains are released  
(d) Treating the plants with low concentrations of gibberellic acid and auxins
- Gibberellins can promote seed germination because of their influence on [AIIMS 2005; NEET 2013]  
(a) Rate of cell division  
(b) Production of hydrolyzing enzymes  
(c) Synthesis of abscissic acid  
(d) Absorption of water through hard seed coat
- Dormancy of seed is broken by  
[RPMT 2002; Pb. PMT 2004; WB JEE 2016]  
(a) Auxin and Cytokinin (b) Gibberellins and ethylene  
(c) Ethylene and auxin (d) Cytokinin and auxin

- Apical dominance is not affected by [MP PMT 2001]  
(a) Indole acetic acid (b) Gibberellic acid  
(c) Indole acetaldehyde (d) Indole butyric acid
- The hormone which was discovered through 'foolish seedling' disease of rice is  
[AIIMS 1994; CBSE PMT 2007; BHU 2008]  
Or  
Bakane disease in paddy is caused by  
[VITEEE 2006; WB JEE 2009]  
(a) Indole-3-acetic acid (b) Ethylene  
(c) Gibberellic acid (d) Kinetin
- Gibberellins were first discovered in fungal genus [MP PMT 1999]  
(a) *Mucor* (b) *Rhizopus*  
(c) *Agaricus* (d) *Fusarium*
- The rosette habit of cabbage can be changed by application of [KCET 2011]  
(a) IAA (b) GA  
(c) ABA (d) Ethaphon
- At the onset of seed germination, the digestive enzymes amylase are produced by the action of [BHU 2005; AMU (Med.) 2006]  
Or  
The activity of  $\alpha$  amylase in the endosperm of barley germinating seed is induced by [MP PMT 2002]  
(a) Auxins (b) Gibberellins  
(c) Cytokinins (d) Ethylene
- The chemical nature of gibberellins is that they are [KCET 2006]  
(a) Acidic (b) Alkaline  
(c) Proteinaceous (d) Amines
- The gibberellins are plant growth hormones. They cause elongation of stems. Gibberellin was first isolated by Japanese workers from [CPMT 1993, 94, 2003; AIEEE Pharmacy 2003; DPMT 2004]  
(a) Endosperm of barley (b) Sporophyte of moss  
(c) A parasitic fungus (d) Scutellum of rice

**Cytokinin**

- Cytokinin is a hormone whose main function is  
[AFMC 1997, 2000, 12; CPMT 2000, 10; AIIMS 2001; BHU 2004; Odisha JEE 2004]  
(a) Induction of cell division and delay in senescence  
(b) To take part in cell division  
(c) Refers to cell movements  
(d) To cause dormancy
- Richmond Lang effect can be observed in plants by the treatment of [MP PMT 1993; Odisha JEE 2012]  
(a) Cytokinin (b) Ethylene  
(c) Abscissic acid (d) Gibberellins
- A plant hormone used for inducing morphogenesis in plant tissue culture is [CBSE PMT 1998]  
Or  
For plant tissue culture among the following which one is required  
(a) Abscissic acid (b) Gibberellins  
(c) Cytokinins (d) Ethylene

4. Cytokinesis refers to [KCET 1994]  
(a) Division of chromosomes (b) Division of cytoplasm  
(c) Division of nucleus (d) None of these
5. Leaf fall can be prevented by  
(a) Florigen (b) Auxin  
(c) Cytokinins (d) Abscissic acid
6. Which of the following induces flowering in short day plant [AFMC 1997]  
(a) Gibberellins (b) Cytokinin  
(c) Auxins (d) Ethylene
7. All the cytokinins are [MP PMT 1996]  
(a) Acidic (b) Aminopurines  
(c) Phenol (d) Glucosides
8. Pick out the correct statements  
(A) Cytokinins specially help in delaying senescence  
(B) Auxins are involved in regulating apical dominance  
(C) Ethylene is especially useful in enhancing seed germination  
(D) Gibberellins are responsible for immature falling of leaves [Kerala PMT 2008]  
(a) A and C only (b) A and D only  
(c) B and C only (d) A and B only  
(e) B and D only
9. Which of the following is a coconut milk factor [NCERT; CBSE PMT 2000, 03; Manipal 2005; J & K CET 2008; AFMC 2009]  
(a) Auxin (b) Cytokinin  
(c) Morphactin (d) None of the above
10. Match the following and choose the correct combination  

Column I	Column II
A. Zeatin	1. Flowering hormone
B. Florigen	2. Synthetic auxin
C. IBA	3. Cytokinin
D. NAA	4. Natural auxin

[Kerala PMT 2009]  
(a) A—3, B—4, C—1, D—2  
(b) A—2, B—1, C—4, D—3  
(c) A—1, B—2, C—3, D—4  
(d) A—4, B—1, C—2, D—3  
(e) A—3, B—1, C—4, D—2
11. Farmers in a particular region were concerned that premature yellowing of leaves of a pulse crop might cause decrease in the yield. Which treatment could be most beneficial to obtain maximum seed yield [CBSE PMT 2006; AIIMS 2007]  
(a) Removal of all yellow leaves and spraying the remaining green leaves with 2, 4, 5-trichlorophenoxy acetic acid  
(b) Application of iron and magnesium to promote synthesis of chlorophyll  
(c) Frequent irrigation of the crop  
(d) Treatment of the plants with cytokinins along with a small dose of nitrogenous fertilizer
12. Cytokinins are formed in [NCERT; BVP 2004]  
(a) Roots (b) Leaves  
(c) Fruits (d) Stems
13. An excised leaf does not turn yellow if it is induced to root. This is attributed to synthesis in root of or Leaf aging is retarded by [BHU 2003]  
Or  
The cut flowers and vegetables can be kept fresh a long period by this plant hormone [Kerala PMT 2004; KCET 2012]  
(a) Ethylene (b) Cytokinins  
(c) Gibberellins (d) Auxins
14. Which of the following is indispensable in all culture  
(a) Gibberellin (b) Kinetin  
(c) Ethylene (d) Auxin
15. Cambial tissue of *Pinus radiata* contains  
(a) Auxins (b) Gibberellins  
(c) Cytokinin (d) None of the above
16. Guttman (1957) found a quick increase in the amount of RNA in the nuclei on onion root after  
(a) Auxin treatment (b) Kinetin treatment  
(c) Gibberellin treatment (d) All the above
17. RNA formation is induced by  
(a) Phylloclalins (b) All calins  
(c) Kinetins (d) Florigens
18. Cytokinin was first synthesized by [RPMT 1995; BVP 2003]  
Or  
Name 'zeatin' was given by [RPMT 1995; J & K CET 2002; BVP 2003]  
(a) Skoog and Miller (b) Letham  
(c) Bensen and Calvin (d) Thimman and Went
19. The natural plant hormone isolated from corn kernels and coconut milk is [Kerala PMT 2007]  
(a) Florigen (b)  $GA_3$   
(c) Free auxins (d) Zeatin  
(e) Indole acetic acid

### Ethylene

1. Pineapple can be made to flower in off season by [NCERT]  
(a) Ethylene/NAA (b) Zeatin  
(c) Short day (d) Temperature
2. Ethylene gas [BHU 1994]  
(a) Is a saturated hydrocarbon  
(b) Slows down the ripening of apples  
(c) Retards ripening of tomatoes  
(d) Speeds up maturation of fruits and early ripening of some fruits
3. The phytohormone which induces triple response is [J & K CET 2008]  
(a) IAA (b) ABA  
(c)  $GA_3$  (d)  $C_2H_4$
4. Ethylene is a [BHU 1994; Bihar MDAT 1995; RPMT 1999; BVP 2000; Pb. PMT 2004; HP PMT 2005; WB JEE 2009]  
(a) Gaseous hormone (b) Gaseous enzyme  
(c) Liquid-gas mixture (d) Solid hormone
5. A higher proportion of ethylene is found in  
(a) Ripening banana (b) Green banana  
(c) Green apple (d) Fresh potato tuber

6. The most efficient precursor of ethylene is  
(a) Adenine (b) Thiocarbamate  
(c) Zeation (d) Methionine
7. The ripening of fruits can be hastened by treatment with  
[NCERT;  
CPMT 1994, 2001, 03, 09; MP PMT 1994, 2005;  
BHU 1995, 2000; KCET 2000; Odisha JEE 2004;  
HP PMT 2005; AMU (Med.) 2006; Kerala PMT 2009]  
(a) Gibberellic acid (b) Indole acetic acid  
(c) Florigen (d) Ethylene gas
8. Which of the following is called as *phytojerontological hormone*  
(a) Ethylene (b) Auxin  
(c) Gibberellin (d) Cytokinin
9. Which one of the following responses of plants to growth hormones is true for ethylene [MP PMT 1995]  
(a) Increase in cell elongation  
(b) Decrease in the formation of female flowers  
(c) Increase in ripening of fruits  
(d) Decrease in abscission of flowers
10. Artificial ripening of which of the following fruits is useless [CBSE PMT 1992]  
(a) Mango (b) Banana  
(c) Grapes (d) Pomegranate/Coconut
11. Root development is promoted by [CBSE PMT (Maine) 2010]  
(a) Absciscic acid (b) Auxin  
(c) Gibberellin (d) Ethylene
12. Which combination of gases is suitable for fruit ripening [CBSE PMT 1998]  
(a) 80%  $C_2H_4$  and 20%  $CO_2$  (b) 80%  $CO_2$  and 20%  $CH_2$   
(c) 80%  $CH_4$  and 20%  $CO_2$  (d) 80%  $CO_2$  and 20%  $O_2$
13. Which hormone causes stunted growth in pea [MHCET 2003]  
(a) Gibberellic acid (b) Auxin  
(c) Cytokinin (d) Ethylene

### ABA and Other growth regulators

1. Absciscic acid controls [CBSE PMT 1990, 99; EAMCET 1995]  
(a) Shoot elongation  
(b) Cell elongation and cell wall formation  
(c) Cell division  
(d) Leaf fall and dormancy
2. The following is a naturally occurring growth inhibitors [CPMT 1996; AFMC 2010]  
(a) IAA (b) ABA  
(c) NAA (d) GA
3. Which one of the following acids is a derivative of carotenoids [CBSE PMT 2009]  
Or  
One of the most commonly detected inhibitor of germination is [JIPMER 2002]  
(a) Indole butyric acid (b) Indole-3-acetic acid  
(c) Gibberellic acid (d) Absciscic acid
4. Wound hormone is called  
(a) Necrohormone (b) Hormone only  
(c) Auxins (d) Phyllocaline

5. Maleic hydrazide is used to  
(a) To prolong dormancy (b) To break dormancy  
(c) Both (a) and (b) (d) None of the above
6. Match List I and List II and select the correct option

List I		List II	
A.	Auxin	1.	Herring sperm DNA
B.	Cytokinin	2.	Inhibitor of growth
C.	Gibberellin	3.	Apical dominance
D.	Ethylene	4.	Epinasty
E.	Absciscic acid	5.	Induces amylase synthesis

[Kerala PMT 2008]

- (a) A-3, B-1, C-5, D-4, E-2  
(b) A-4, B-5, C-1, D-3, E-2  
(c) A-2, B-1, C-5, D-3, E-4  
(d) A-3, B-1, C-5, D-2, E-4  
(e) A-4, B-1, C-5, D-3, E-2
7. "Morphactins" are  
(a) Synthetic growth regulators (b) Synthetic auxins  
(c) Synthetic gibberellins (d) None of the above
8. Elongation of internodes is inhibited by  
(a) Gibberellins (b) Morphactins  
(c) Both (a) and (b) (d) None of the above
9. One hormone helps in ripening of fruits while the other stimulates closure of stomata. These are respectively [Kerala PMT 2008]  
(a) Absciscic acid and auxin  
(b) Ethylene and absciscic acid  
(c) Absciscic acid and ethylene  
(d) Ethylene and gibberellic acid  
(e) Gibberellic acid and absciscic acid
10. Match the items in Column - I with Column - II and choose the correct option

Column - I		Column - II	
A.	Human urine	1.	Cytokinin
B.	<i>Gibberella fujikuroi</i>	2.	Auxin
C.	Herring fish DNA	3.	Ethylene
D.	Ripening fruits	4.	Absciscic acid
E.	Aged leaves of plants	5.	Gibberellins

[Kerala PMT 2007]

- (a) A-2, B-5, C-1, D-3, E-4  
(b) A-2, B-3, C-4, D-5, E-1  
(c) A-1, B-5, C-2, D-4, E-3  
(d) A-5, B-4, C-3, D-2, E-1  
(e) A-3, B-2, C-1, D-5, E-4
11. Which one of the following generally acts as an antagonist to gibberellins [NCERT; CBSE PMT (Maine) 2012; BHU 2012]  
(a) Zeatin (b) Ethylene  
(c) ABA (d) IAA
12. Absciscic acid treatment results in [CBSE PMT 1991; Odisha JEE 2005; GUJCET 2007; J & K CET 2010]  
(a) Leaf expansion (b) Stem elongation  
(c) Stomatal closure (d) Root elongation

13. Which plant hormone promotes seed, bud dormancy and causes stomatal closure [CBSE PMT 1999; AIIMS 1999, 2002; DPMT 2006; WB JEE 2008]

Or

Presence of which of the following in seed is associated with dormancy [CBSE PMT 1999; BVP 2002]

Or

Leaf abscission, fruit fall, bud dormancy occurs by which Phytohormone [CPMT 1998; AFMC 2004; BHU 2006; J & K CET 2010]

- (a) IAA (b) Abscissic acid  
(c) GA<sub>1</sub> (d) Cytokinin
14. In the extreme drought condition which of the following plant hormone is produced due to which stomata closes [AMU (Med.) 2005; J & K CET 2012]

(a) ABA (b) I.A.A  
(c) Gibberellin (d) Ascorbic acid

15. Choose the wrongly matched pair from the following [Kerala PMT 2006]

(a) Auxins – "to grow"  
(b) Gibberellins – *Gibberella fujikurui*  
(c) Cytokinins – Herring sperm DNA  
(d) Abscissic acid – Flowering hormone  
(e) Ethylene – Gas hormone

16. Phytostron is [CPMT 2003]

(a) Fish culture (b) Plant hormone  
(c) Animal hormone (d) None of these

17. The shedding of leaves, flowers or fruits due to change in the hormonal balance in plant is referred as [J & K CET 2005]

(a) Senescence (b) Abscission  
(c) Photoperiodism (d) Vernalisation

18. Which one of the following plant hormones (Phytohormone) is known as a stress hormone [NCERT; MHCET 2000; MP PMT 2006; WB JEE 2008; AIIMS 2012; CBSE PMT 2014]

(a) Gibberellins (b) Kinetin  
(c) Auxin (d) Abscissic acid

19. Which of the following hormone is responsible for senescence [CBSE PMT 2001]

(a) GA (b) ABA  
(c) Auxin (d) Cytokinin

### Photoperiodism and Vernalization

1. The response of different organisms to the environmental rhythms of light and darkness is called [CBSE PMT 1998; Kerala PMT 2009]

Or

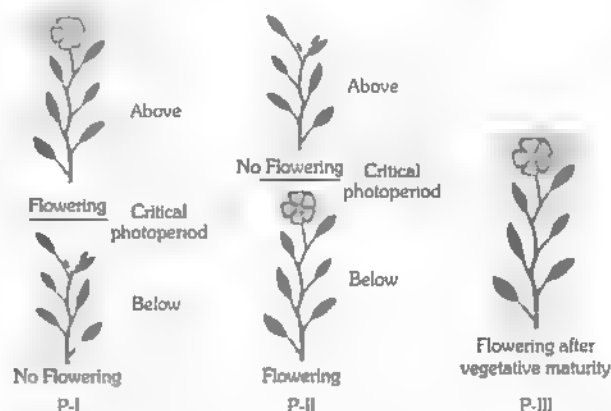
The effect of daily light period on flowering is called [CPMT 1999]

(a) Phototaxis (b) Phototropism  
(c) Vernalization (d) Photoperiodism

2. With which of the following process *Cholodny-Went theory* is concerned [Odisha JEE 2008]

(a) Phototropism (b) Photomorphogenesis  
(c) Photorespiration (d) Photoperiodism

3. See the following experiment and observe the result



Now identify plants (P - I, II and III) [NCERT]

- (a) P - I = Long day plant; P - II = Long day plant; P - III = Day neutral plant  
(b) P - I = Short day plant; P - II = Short day plant; P - III = Day neutral plant  
(c) P - I = Short day plant; P - II = Long day plant; P - III = Day neutral plant  
(d) P - I = Long day plant; P - II = Short day plant; P - III = Day neutral plant

4. The red absorbing form of phytochrome gets converted to the far-red absorbing form after getting irradiated at [BHU 1994]

(a) 660 nm (b) 730 nm  
(c) 530 nm (d) 660 nm to 730 nm

5. The pigment involved in red-far red light interconversion is [CPMT 1994; CBSE PMT 1995, 2002]

Or

The pigment involved in photomorphogenetic movements is [BHU 2000]

Or

Pigment involved in photo-perception in flowering is

(a) Cytochrome (b) Xanthophyll  
(c) Lycopene (d) Phytochrome

6. Importance of day length (Photoperiodism) in flowering of plants was first shown in [CBSE PMT 2008; CBSE PMT (Pre.) 2010]

(a) Cotton (b) *Petunia*  
(c) *Lemna* (Photoperiodism) (d) Tobacco

7. *Nicotiana sylvestris* flowers only during long days and *N. tabacum* flowers only during short days. If raised in the laboratory under different photoperiods, they can be induced to flower at the same time and can be cross fertilized to produce self-fertile offspring. What is the best reason for considering *N. sylvestris* and *N. tabacum* to be separate species [AIIMS 2007]

(a) They are physiologically distinct  
(b) They are morphologically distinct  
(c) They cannot interbreed in nature  
(d) They are reproductively distinct

8. Phytochrome is found in [MP PMT 2007]  
(a) Algae (b) Fungi  
(c) Vascular cryptogams (d) Flowering plants
9. Effect of length of day (light duration) on flowering is called [JIPMER 2001]  
(a) Phototropism (b) Photoperiodism  
(c) Photorespiration (d) None of the above
10. *Saccharum officinarum* grows well in [Odisha JEE 2008]  
(a) Low temperature (b) Swampy area  
(c) Dry and arid condition (d) Moist condition
11. When the dark period of short day plants is interrupted by a brief exposure of light, then the plant [CBSE PMT 1994]  
(a) Will not flower at all  
(b) Flower immediately  
(c) Give more flowers  
(d) Turn into a long day plant
12. Which of the following hormones can replace vernalization [BHU 1994]  
Or  
Genetic dwarfness can be overcome by treating with [MHCET 2003]  
(a) Auxin (b) Ethylene  
(c) Gibberellins (d) Cytokinins
13. Which of the following is a short day plant [HP PMT 2005]  
(a) Wheat (b) Barley  
(c) Larkspur (d) *Dahlia*
14. What helps in flowering [DPMT 2006; Odisha JEE 2012]  
(a) Cytochrome (b) ABA  
(c) C-phytochrome (d) Ethylene
15. Vernalisation stimulates flowering in [NCERT; CBSE PMT (Mains) 2012]  
(a) Zamikand (b) Turmeric  
(c) Carrot (d) Ginger
16. Photoperiodic stimulus is received by [MP PMT 1999]  
(a) Leaves (b) Buds  
(c) Meristem (d) Flowers
17. Biological clock in plants is controlled by [BHU 2012]  
(a) Phytochrome (b) Cryptochrome  
(c) Both (a) and (b) (d) Gibberellin
18. The period of suspended growth due to exogenous condition is termed as [J & K CET 2005]  
(a) Quiescence (b) Dormancy  
(c) Perennation (d) Hibernation
19. Short day plant is [Odisha JEE 2005]  
(a) *Xanthium* (b) *Pisum*  
(c) *Cucumis* (d) *Avena*
20. Through their effect on plant growth regulators, what do the temperature and light control in the plants [NCERT; CBSE PMT (Mains) 2012]  
(a) Apical dominance (b) Flowering  
(c) Closure of stomata (d) Fruit elongation
21. Photoperiodism is substituted by [MP PMT 2005]  
(a) Temperature (b) Mineral nutrient  
(c) Vit. (d) Iron
22. If plants are given only visible light its growth will [MP PMT 2005]  
(a) Increase (b) Decrease  
(c) Unusual form (d) None of these
23. Phytochrome occurs in two forms. In which form it promotes the germination of seeds of some species [CPMT 1995, 2004]  
(a)  $P_r$  forms (b)  $P_f$  forms  
(c) Both forms (d) None of these
24. When flowering is regulated by length of day and night, it is called [Odisha JEE 2004; MP PMT 2012]  
(a) Photoperiodism (b) Phototropism  
(c) Nyctinasty (d) None of these
25. Most of the plants are seasonal due to [MP PMT 1997]  
(a) Photoperiodism (b) Phototropism  
(c) Photosynthesis (d) Photolysis
26. Name 'phytochrome' was given by [MP PMT 2001]  
(a) Mothes (b) Borthwick and Hendrick  
(c) Sorokin *et al* (d) Wickson and Thimman
27. One set of a plant was grown at 12 hours day and 12 hours night period cycles and it flowered while in the other set night phase was interrupted by flash of light and it did not produce flower. Under which one of the following categories will you place this plant [CBSE PMT 2004]  
(a) Day neutral (b) Short day  
(c) Long day (d) Darkness neutral
28. The low temperature treatment that reduces the period between sowing and flowering is called [BHU 1999, 2006; CPMT 2000; DPMT 2003, 04; VVP 2004; AMU (Med.) 2005, 06; HP PMT 2005; Kerala PMT 2006]  
Or  
The practice of subjecting seeds to low temperatures for a period of time in order to cause growth and flowering during summer season is called [CBSE PMT 1992; WB JEE 2016]  
(a) Chemotaxis (b) Vernalization  
(c) Freezing injury (d) None of the above
29. Phytochrome is closely related to [RPMT 1999]  
(a) Chlorophyll 'e' (b) Bacterio chlorophyll  
(c) Phycocyanin 'c' (d) Carotinoid
30. Treatment of seed at low temperature under moist conditions to break its dormancy is called [CBSE PMT 2006]  
(a) Chelation (b) Stratification  
(c) Scarification (d) Vernalization
31. In SDP flowering does not occur [BHU 2003]  
(a) When intermediate light is given red  $\rightarrow$  far red  $\rightarrow$  red  
(b) Interrupted by a flash of far light  
(c) Interrupted by a flash red  $\rightarrow$  far light  
(d) All of these

32. The term "photoperiodism" was proposed by or The phenomenon of photoperiodism in plants was discovered by [MP PMT 1994, 98, 2002, 12]
- Lysenko and Thimman
  - Blackman and Skoog
  - Gamer and Allard
  - Chailakhyan and Borthwick
33. A hypothetical chemical involved in the flowering of plants is or Chemical agent which has important role in flowering is [CBSE PMT 1991]
- Gibberellin
  - Kinetin
  - Indole acetic acid
  - Florigen
34. Phytochrome is used in [RPMT 1992; Kerala CET 2001, 03]
- Flowering only
  - Seed germination only
  - Transpiration only
  - All physiological processes exhibited by the plants such as seed germination, flowering (photoperiodism), stem elongation and transpiration
35. In short day plants (SDP) flowering is induced by [CBSE PMT 1992]
- Long night
  - Photoperiod less than 12 hours
  - Photoperiod shorter than initial value and uninterrupted long night
  - Short photoperiod and interrupted long night
36. If a tree flowers thrice in a year (October, January and July) in Northern India, it is said to be [CBSE PMT 1997]
- Photosensitive but thermo-insensitive
  - Thermosensitive but photo-insensitive
  - Photo and thermo-insensitive
  - Photo and thermosensitive
37. For germination of seed, which light is necessary [AFMC 1996]
- Or
- Which wavelength of light is responsible for best flowering [MP PMT 2011]
- Red light
  - Green light
  - Far-red light
  - Blue light
38. Phytochrome becomes active in [MP PMT 1998; CBSE PMT 1998]
- Green light
  - Blue light
  - Red light
  - None of these
39. Phytochrome is [MP PMT 1993]
- Absorption of blue light by leaves
  - Absorption of PR and PFR in reversible manner
  - Absorption of red light with wavelength  $660m\mu$
  - Absorption of far-red light with wavelength  $740m\mu$
40. A pigment concerned with both floral induction and seed germination is [MP PMT 2002; CPMT 2010]
- Florigen
  - Chlorophyll
  - Plastocyanin
  - Phytochrome
41. Photoperiodism affects [MP PMT 2001]
- Vegetative growth
  - Internode elongation
  - Seed germination
  - All of these
42. Florigen is synthesized in [RPMT 1995]
- Stem
  - Leaves
  - Root
  - Fruits
43. With respect to photoperiodism, these are long day plant [MP PMT 2007; GUJCET 2007]
- Wheat, oat, soyabean
  - Wheat, *Xanthium*, paddy
  - Wheat, poppy, soyabean
  - Wheat, poppy, beet
44. Which of the following is a long day plant [CBSE PMT 2001; AFMC 2010]
- Mirabilis*
  - Glycine max*
  - Mirabilis jalapa*
  - Spinacia oleracea* (Spinach)
45. What is the action spectrum of photoperiodism
- 430 and 660 nm
  - 640 and 660 nm
  - 660 and 730 nm
  - 700 and 900 nm
46. Proteinaceous pigment which is the centre of activities concerned with light is [CBSE PMT 2001]
- Phytochrome
  - Chlorophyll
  - Anthocyanin
  - Carotenoids
47. A few normal seedlings of tomato were kept in a dark room. After a few days they were found to have become white-coloured like albinos. Which of the following terms will you use to describe them [Bihar MDAT 1995; DUMET 2009; CBSE PMT 2014]
- Etiolated
  - Defoliated
  - Mutated
  - Embolised
48. The wavelength of light absorbed by Pr form of phytochrome is [CBSE PMT 2007]
- 640 nm
  - 680 nm
  - 720 nm
  - 620 nm
49. Phytochrome is sensitive to [BHU 2001; Pb. PMT 2004]
- Red light
  - Far red light
  - Green light
  - Both (a) and (b)
50. *Chrysanthemum* flowers either in winter season or in evening because it is a [J & K CET 2008]
- Short-day plant
  - Long-day plant
  - Day-neutral plant
  - Mid-day plant
51. Phytochrome is a [NEET (Phase-II) 2016]
- Chromoprotein
  - Flavoprotein
  - Glycoprotein
  - Lipoprotein
52. Plants which disregard the requirement of a definite day length for the flowering are called [WB JEE 2016]
- Short day plants
  - Long day plants
  - Day neutral plants
  - Long short-day plants



# NQ NCERT

## Exemplar Questions

- The photoperiod in plants is perceived at [NCERT]  
(a) Meristem (b) Flower  
(c) Floral buds (d) Leaves
- The effect of apical dominance can be overcome by which of the following hormone [NCERT]  
(a) IAA (b) Ethylene  
(c) Gibberellin (d) Cytokinin
- Match the following  
A. IAA I. Herring sperm DNA  
B. ABA II. Bolting  
C. Ethylene III. Stomatal closure  
D. GA IV. Weed-free lawns  
E. Cytokinins V. Ripening of fruits  
Options [NCERT]  
(a) A-iv, B-iii, C-v, D-II, E-I  
(b) A-v, B-iii, C-iv, D-II, E-I  
(c) A-iv, B-I, C-v, D-iii, E-II  
(d) A-v, B-iii, C-II, D-I, E-iv
- Apples are generally wrapped in waxed paper to [NCERT]  
(a) Prevent sunlight for changing its colour  
(b) Prevent aerobic respiration by checking the entry of  $O_2$   
(c) Prevent ethylene formation due to injury  
(d) Make the apples look attractive
- Growth can be measured in various ways. Which of these can be used as parameters to measure growth [NCERT]  
(a) Increase in cell number  
(b) Increase in cell size  
(c) Increase in length and weight  
(d) All the above
- The term synergistic action of hormones refers to [NCERT]  
(a) When two hormones act together but bring about opposite effects  
(b) When two hormones act together and contribute to the same function  
(c) When one hormone affects more than one function  
(d) When many hormones bring about any one function
- Plasticity in plant growth means that [NCERT]  
(a) Plant roots are extensible  
(b) Plant growth is dependent on the environment  
(c) Stems can extend  
(d) None of the above
- To increase sugar production in sugarcane, they are sprayed with [NCERT]  
(a) IAA (b) Cytokinin  
(c) Gibberellin (d) Ethylene
- Monocarpic plants are those which [NCERT]  
(a) Bear flowers with one ovary  
(b) Flower once and die  
(c) Bear only one flower  
(d) All of the above

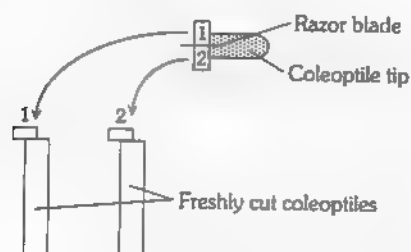
# GT Critical Thinking

## Objective Questions

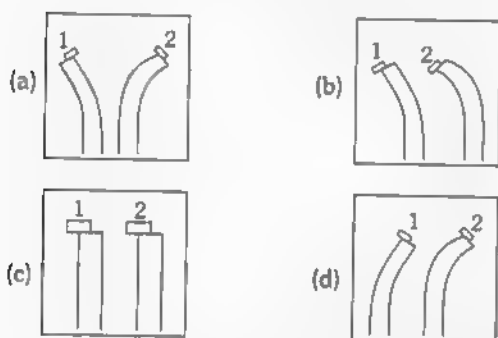
- During cell enlargement phase of growth, molecules of new cell wall material are inserted between the original molecules of stretched wall. This process is known as  
(a) Intussusception (b) Apposition  
(c) Integration (d) None of the above
- Senescence as an active developmental cellular process in the growth and functioning of a flowering plant, is indicated in [CBSE PMT 2008]  
(a) Annual plants  
(b) Floral parts  
(c) Vessels and tracheid differentiation  
(d) Leaf abscission
- Phytohormones are [CBSE PMT 1990; AFMC 2006]  
(a) Hormones regulating growth from seed to adulthood  
(b) Growth regulators synthesised by plants and influencing physiological processes  
(c) Hormones regulating flowering  
(d) Hormones regulating secondary growth
- Identify two physiological processes induced by two different phytohormones having a common precursor which is formed due to the catalytic activity of pyruvic dehydrogenase complex  
(I) More female flowers in cucumber  
(II)  $\alpha$ -amylase production in barley grain  
(III) Acceleration of fruit ripening in tomato  
(IV) Delay in sprouting of potato tubers  
The correct combination is [IAMCET 2009]  
(a) I, II (b) I, III  
(c) II, IV (d) III, IV
- Choose the correct sequence of stages of growth curve for bacteria [AIIMS 2007]  
(a) Lag, log, stationary, decline phase  
(b) lag, log, stationary phase  
(c) Stationary, lag, log, decline phase  
(d) Decline, lag, log phase
- Which of the following is more essential for the breaking of seed dormancy [Odisha JEE 2008; MHCET 2011]  
(a) Light (b) Heat  
(c) Cold (d) Moisture
- Mowing on a grass lawn facilitates better maintenance primarily owing to [JIPMER 1994]  
(a) Removal of apical dominance and promotion of lateral meristem  
(b) Removal of apical dominance  
(c) Wounding which stimulates rapid regeneration  
(d) None of the above

8. Apical dominance means
- Suppression of growth of apical bud by axillary buds
  - Suppression of growth of axillary buds by presence of apical bud
  - Stimulation of growth of apical bud by removal of axillary buds
  - Inhibition of growth of axillary buds by removal of apical bud
9. Clinostat is the apparatus used to
- Measure the rate of growth in plant
  - Measure the quantity of auxin in plant
  - Measure the effect of light on plant
  - Eliminate the effect of gravity on plant
10. Which of the following statement is false with respect to application of auxins
- Control direction of growth of plants
  - Inhibits lateral bud growth
  - Initiate and promote cell division actively particularly in tissue culture
  - Produce hyperelongation effect
11. A green plant bends towards the source of light when exposed to the light on only one side, it bends towards the source of light as it grows. Which of the following is the best explanation of the phenomenon [AIPMT (Cancelled) 2015]
- The apices of their stems are attracted by light
  - They need light for photosynthesis
  - Some auxins accumulates on the shaded side to induce greater cell elongation on that side
  - Light stimulates the cells on the illuminated side to increase in length
12. What will be the effect on phytochrome in a plant subjected to continuous red light [CBSE PMT 1997]
- Level of phytochrome will decrease
  - Phytochrome will be destroyed
  - Phytochrome synthesis will increase
  - None of these
13. Exogenous application of gibberellins induces male flower formation on genetically female plants in
- Carica*
  - Cucumis*
  - Coccinia*
  - Cucurbita*
14. A genetically dwarf plant can be converted into a tall plant by the use of [MP PMT 1996]
- Kinetin
  - $GA_3$
  - IAA/X-rays
  - 2, 4-D
15. One hormone is used to speed up the malting process in barley, another is used to promote flowering in pineapple, while the third helps in the delay of leaf senescence. These are respectively [Kerala PMT 2012; AMU (Med) 2012]
- Auxin, gibberellin and cytokinin
  - Gibberellin, cytokinin and auxin
  - Gibberellin, auxin and cytokinin
  - Cytokinin, auxin and gibberellin
  - Auxin, cytokinin and gibberellin
16. The ripening of fruits can be accelerated by
- Reducing the supply of water to plant when fruits are maturing
  - Increasing the supply of nitrogen to the atmosphere surrounding them
  - Warming up the surroundings artificially
  - Artificially adding ethylene gas to the atmosphere surrounding them
17. Which one of the following statements is true for the phytochrome [MP PMT 1995]
- Phytochrome is a phytohormone
  - Phytochrome is a photosynthetic pigment
  - Phytochrome is a pigment that controls growth, photomorphogenesis and development of many plants
  - Phytochrome is a regulatory protein that controls several dark-dependent developmental processes
18. Which one of the following synthetic growth regulators is used to promote synchronized flowering in pineapple [KCET 2010]
- Benzyl aminopurine
  - Phenylmercuric acetate
  - Indolebutyric acid
  - 2-chloroethylphosphoric acid
19. Which one of the following pairs is incorrectly matched [NCERT; Kerala PMT 2011]
- |     |                       |   |          |
|-----|-----------------------|---|----------|
| (a) | Adenine derivative    | - | Kinetin  |
| (b) | Carotenoid derivative | - | ABA      |
| (c) | Terpenes              | - | IAA      |
| (d) | Indole compounds      | - | IBA      |
| (e) | Gas                   | - | Ethylene |
20. The viability of seeds is tested by [NEET (Karnataka) 2013]
- 2, 6 dichlorophenol indophenols
  - 2, 3, 5 triphenyl tetrazolium chloride
  - DMSO
  - Safranin
21. The given figure shows four coleoptiles set up at the start of an experiment
- 
- Which two coleoptiles will bend towards the light source [NCERT]
- 3 and 4
  - 2 and 3
  - 1 and 4
  - 1 and 2

22. Two blocks of Agar 1 and 2 were kept in the positions shown in the diagram below for several hours and then transferred into two freshly cut coleoptiles



After two days of growth which of the following would result [NCERT]



23. One hormone hastens maturity period in juvenile conifers, a second hormone controls xylem differentiation, while the third increases the tolerance of plants to various stresses they are respectively [KCET 2015]

- Gibberellin, Auxin, Cytokinin
- Auxin, Gibberellins, Cytokinin
- Gibberellin, Auxin, ABA
- Auxin, Gibberellins, ABA

24. Which of the following enhances or induces fusion of protoplasts [AIPMT (Cancelled) 2015]

- Polyethylene glycol and sodium nitrate
- IAA and kinetin
- IAA and gibberellins
- Sodium chloride and potassium chloride

25. Seed dormancy can be broken by the following combination of chemicals [WB JEE 2016]

- $GA_3$ , IAA and ABA
- $KNO_3$ ,  $GA_3$  and Ethylene chlorohydrin
- NAA, 2,4,5-T and IAA
- ABA, BAP and  $GA_3$

26. Seedless fruits can be induced by [WB JEE 2016]

- ABA and IAA
- ABA and Zeatin
- IAA and  $GA_3$
- Ethylene and ABA

## Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

- If both the assertion and the reason are true and the reason is a correct explanation of the assertion
- If both the assertion and reason are true but the reason is not a correct explanation of the assertion
- If the assertion is true but the reason is false
- If both the assertion and reason are false
- If the assertion is false but reason is true

1. Assertion : Gibberellins induce flowering in long day plants.

Reason : Genetically tall plant become dwarf by application of Gibberellin. [AIIMS 1994]

2. Assertion : Agent orange is a mixture of 2,4-D and 2,4,5-T, used during Vietnam War.

Reason : 2,4-D and 2,4,5-T are used as herbicides.

3. Assertion : Auxins promote apical dominance by suppressing the activity of lateral buds.

Reason : In moriculture, periodic pruning of shoot tips is done to make mulberry plants bushy.

[KCET 2009]

4. Assertion : "Touch" responses in *Mimosa* is an example of such movement.

Reason : Nastic movements occur in the direction of stimulus.

5. Assertion : Photomodulation of flowering is phytochrome-regulated process.

Reason : Active form of phytochrome (Pfr) directly induces floral induction in shoot buds.

[AIIMS 2004]

6. Assertion : Secondary roots and shoots are plagiogeotropic.

Reason : Plagiogeotropic roots are those which develop at an angle of  $45^\circ$  from the vertical axis.

7. Assertion : The apical bud is the only source of auxins.

Reason : Removal of apical bud promotes lateral bud growth.

8. Assertion : Cytokinin are antisenescence.

Reason : Effects of cytokinins is antagonistic to ethylene.

9. Assertion : Ethylene cause climacteric ripening of fruits.  
Reason : Climacteric fruits show a rise in respiration at the time of ripening.
10. Assertion : Stratification of seeds may promote their germination.  
Reason : Stratification promote gibberellin and cytokinins.
11. Assertion : Sigmoid growth curve consists of four parts.  
Reason : Lag phase is called as grand phase of growth.
12. Assertion : Dark period play more important part in flowering than light period.  
Reason : Flowering occurs in short-day plant if the dark period is interrupted by light break.
13. Assertion : Phototropism is a directional growth movement.  
Reason : Phototropic movement occur in the direction of light.
14. Assertion : Phytochrome exists in two form  $P_r$  and  $P_f$ .  
Reason :  $P_r$  form stimulates and  $P_f$  form inhibit flowering.
15. Assertion : Floral initiation is done by florigen.  
Reason : Florigen is translocated from flowers to leaves.
16. Assertion : Vernalization is a treatment to plant given artificially.  
Reason : Vernalization is perceived by whole plant.
17. Assertion : Plant growth as a whole is indefinite.  
Reason : Plants retain the capacity of continuous growth throughout their life. [AIIMS 2011]

## Answers

### Growth

1	c	2	c	3	d	4	a	5	b
6	d	7	d	8	a	9	c	10	c
11	d	12	b	13	c	14	c	15	b
16	d	17	c	18	a	19	b	20	b
21	b	22	b	23	b	24	d	25	c

26	b	27	b	28	c	29	b	30	b
31	a								

### Growth Hormones

1	d	2	a	3	d	4	b	5	b
6	d	7	a	8	d	9	c	10	d
11	c	12	b	13	a	14	a		

### Auxin

1	b	2	c	3	a	4	d	5	c
6	a	7	b	8	a	9	a	10	a
11	b	12	b	13	a	14	d	15	b
16	a	17	c	18	d	19	c	20	c
21	b	22	d	23	d	24	b	25	d
26	a	27	b	28	a	29	b	30	a
31	d	32	a	33	d	34	b	35	b
36	a	37	a	38	b	39	a	40	d
41	a	42	c	43	c				

### Gibberellins

1	a	2	b	3	c	4	a	5	b
6	b	7	b	8	d	9	b	10	b
11	b	12	c	13	d	14	b	15	b
16	a	17	c						

### Cytokinin

1	a	2	a	3	c	4	b	5	c
6	b	7	b	8	d	9	b	10	e
11	d	12	a	13	b	14	b	15	c
16	b	17	c	18	b	19	d		

### Ethylene

1	a	2	d	3	d	4	a	5	a
6	d	7	d	8	a	9	c	10	d
11	d	12	a	13	d				

### ABA and Other growth regulators

1	d	2	b	3	d	4	a	5	a
6	a	7	a	8	b	9	b	10	a
11	c	12	c	13	b	14	a	15	d
16	d	17	b	18	d	19	b		

## Photoperiodism and Vernalization

1	d	2	a	3	d	4	a	5	d
6	d	7	c	8	d	9	b	10	a
11	a	12	c	13	d	14	c	15	c
16	a	17	c	18	b	19	a	20	b
21	a	22	b	23	a	24	a	25	a
26	b	27	b	28	b	29	c	30	b
31	a	32	c	33	d	34	d	35	c
36	b	37	a	38	c	39	b	40	d
41	d	42	b	43	d	44	d	45	c
46	a	47	a	48	a	49	d	50	a
51	a	52	c						

## NCERT Exemplar Questions

1	d	2	d	3	a	4	b	5	d
6	b	7	b	8	c	9	b		

## Critical Thinking Questions

1	a	2	d	3	b	4	d	5	a
6	d	7	b	8	b	9	d	10	c
11	c	12	d	13	b	14	b	15	c
16	d	17	c	18	d	19	c	20	b
21	a	22	d	23	c	24	a	25	b
26	c								

## Assertion and Reason

1	c	2	b	3	a	4	c	5	c
6	a	7	e	8	b	9	b	10	b
11	c	12	c	13	a	14	c	15	c
16	b	17	a						

## AS Answers and Solutions

## Growth

1. (c) Apex portion of root is made up of protective tissue 'root cap' and region of cell division is situated below the root cap.
4. (a) Differential length of light and temperature influence the developmental phase of plant. Photoperiodism and vernalization are the two important factors responsible for the flowering of plants.

6. (d) First phase of growth is cell division, second phase is cell enlargement and third phase is cell maturation.
7. (d) In apical meristem, tissue actively dividing cells are present.
8. (a) Apical meristem are found at shoot and root apex. As a result of activity of these meristems plants increases in length.
9. (c) Because growth is a irreversible process.
10. (c) In glass houses when plants are kept on artificial light and temperature, then this method is called phytotron and is applicable in agriculture, horticulture and tissue culture.
13. (c) Most plants require oxygen for seed germination. That is why soil is ploughed before sowing the seeds.
14. (c) The growth of an organism/organ passes through different phases. If the growth rate of a plant part is plotted against time on a graph paper, a sigmoid/S-shaped growth curve is obtained.
18. (a) It represents initial stage of growth. The rate of growth is very slow in lag phase.
19. (b) Scarification is mechanical or chemical method to soften/weaken hard seed coat by chipping, filing or machine threshing, hot water, fat solvent,  $H_2SO_4$ .
20. (b) Log phase is the rapid growing phase of plants between lag and stationary phase.
27. (b) Auxanometer can register total growth, rate of growth at specific time and overall pattern of growth. In arc auxanometer actual growth in length of a plant is measured as  

$$\text{Actual growth} = \frac{\text{distance travelled by pointer} \times \text{radius of pulley}}{\text{Length of pointer from centre of pulley}}$$
29. (b) Measurement of growth in young root by marking it at 1mm intervals with Indian ink was first done by Strasburger.
30. (b) The existence of first plant growth hormone came from the work of Darwin and Darwin. They found that bending movement of coleoptile of canary grass was due to exposure of tip to unilateral light. Boysen-Jenson found that the tip produces a chemical which was later named auxin.

## Growth Hormones

3. (d) Growth hormones are also called phytohormones term given by Thimann (1948).
5. (b) Seed of many plants including the leguminosae, Malvaceae, Chenopodiaceae, Convolvulaceae and Solanaceae have very hard seed coats. Such seed coats are impermeable to water.
6. (d) By parthenogenesis, seedless fruits are produced but in pomegranate, this process is inapplicable because in it seeds are important.
7. (a) Growth of the plant is very much regulated by certain chemical substances (hormones), which are synthesized by the plant in very small quantities. They are needed in small quantities at very low concentrations as compared to enzyme.
11. (c) Rhizocaline is also called as root forming hormone and it is produced by the leaves and translocated in a polar manner down the stem.

**Auxins**

1. (b) Auxin inhibits abscission of leaves and fruits. Abscission layer is produced when the auxin content falls below a minimum.
2. (c) F.W. Went isolated auxin from *Avena* coleoptile tip.
3. (a) Presence of auxin causes apical dominance in plants and cytokinins are responsible for breaking of apical dominance.
5. (c) Because photosynthesis is enzymatic reaction and it is anabolic process.
7. (b) In presence of auxins unfertilized ovary get changed into fruit.
10. (a) 2, 4-D (2, 4-dichlorophenoxy acetic acid) is a artificial auxin.
14. (d) 2, 4 dichlorophenoxy acetic acid is used as a defoliant for broad leaved plants.
23. (d) Auxins are commonly use in hedge making.
27. (b) Because ethylene is responsible for ripening of fruits. Auxins promote elongations and growth of stems and roots and enlargement of many fruits by stimulating elongation of cells in all direction.
28. (a) Weeds are undesirable in a field with a crop that causes poor yield. 2, 4-D is a famous herbicide or weedicide by which broad-leaved weeds can be destroyed but does not affect mature monocotyledonous plants.
29. (b) Abscission layer is produced when the auxin content falls below a minimum. Application of auxin retards the abscission of leaves, fruits, branches, etc.
31. (d) Many new plants are usually propagated by stem cutting. If we dip to the lower cut end of a cutting in dilute solution of auxins (especially IBA) very soon large number of roots are developed on the cut ends due to which these cutting develop into successful plants.
32. (a) Auxin show polar movement. It is basipetal (from apex to base) in stem but acropetal (from root tip towards shoot) in the root.
34. (b) 2, 4-D is a selective weedkiller. It is highly toxic to broad-leaved plants. It increases carbohydrate metabolism to such an extent that the plants burn themselves to death in dicots.
36. (a) Natural auxins are synthesized in physiologically active parts of plants such as shoot apices, leaf primordial and developing seeds, bud, embryos from amino acid tryptophan
38. (b) Hormones are secreted by cells in one part of the plant and produce their effect in other part of the plant.
39. (a) *Avena* curvature test carried out by F.W. Went demonstrated the effect of auxins on plant growth by performing some experiments with the oat (*Avena sativa*) coleoptile. IAA is the natural auxin.
43. (c) Auxins and cytokinin induce development of root and shoot in a culture medium (respectively)

**Gibberellins**

1. (a) Gibberellins was extracted from rice seedling suffering from 'bakanae disease' which is caused by *Gibberella fujikuroi* fungus.
2. (b) Gibberellins are weakly acidic hormones having gibbane ring structure which cause cell elongation of intact plants in general and increased internodal length of genetically dwarfed plants (i.e., corn, pea) in particular.
3. (c) GA hormone promotes RNA, protein and enzyme synthesis. They helps in germination process.
4. (a) The gibberellins induce elongation of the internodes. The elongation of stem results due to rapid cell division and cell elongation induced by gibberellins.
5. (b) The GA induced bolting in rosettes is exploited commercially to induce early production of seeds.
6. (b) When long day plant are grown under short day conditions the gibberellins are produced in insufficient quantities and flowering does not occur. However if the plant is transferred to long day conditions or gibberellin solution is applied to leaves flowering occurs.
7. (b) Gibberellic acid is mainly related with elongation of plant.
9. (b) Aleurone layer of endosperm releases  $\alpha$ -amylase and protease hydrolytic enzyme, which promotes seed germination.
10. (b) Aleurone layered  $\alpha$ -amylase promotes breaking of seed dormancy.
11. (b) GA promote only plant elongation but the apical dominance by auxins.
12. (c) In 19th century, Japanese farmers observed that the seedlings of rice were abnormally elongated due to infection of fungus *Gibberella fujikuroi*. This effect is called as foolish seedling disease
13. (d) GA 1st discovered from *Gibberella fujikuroi* (*Fusarium moniliforme*) which is of ascomycetous fungus.
15. (b) GA enhances seed germination by enhancing  $\alpha$ -amylase synthesis and thus overcomes dormancy.
17. (c) *Gibberella fujikuroi* is the ascomycetous fungus, which is parasitic in nature.

**Cytokinin**

1. (a) The cytokinin is a true cell division factor, promotes meristematic tissue regions. The cytokinin prevents destruction of chlorophyll in leaves. In presence of kinin the rate of mitotic cell division gets increased. Under this effect when green leaves are kept in cytokinin solution then they become green for long time. So this effect of cytokinin is called as Richmond-Lang effect of senescence.

2. (a) Cytokinins delay the senescence of leaves and other organs by controlling protein synthesis and mobilization. Reported by "Richmond and Lang" in 1957 working on "Xanthium leaves"
3. (c) Cytokinin is a plant hormone which plays a part in organ formation (morphogenesis) with auxin.
4. (b) Cytokinesis – formation of cell after the karyokinesis in the cytoplasm of cell.
5. (c) Cytokinins help in delaying senescence.
6. (b) Cytokinin promotes flowering in some SDP like *Lemna*, *Wolffia*.
7. (b) Bio chemically the cytokinin is aminopurines.
9. (b) In liquid endosperm of coconut kinetin (cytokinins) are present.
12. (a) Cytokinin concentration are highest in meristematic regions and area of continuous growth such as root, young leaves, developing fruits and seed.
13. (b) Cytokinin prevents decolouration of chlorophyll study under Richmond – lang effects. Cytokinin increase shelf life of vegetables and cut flowers and keep them fresh for longer time by preventing deterioration of protein chlorophyll.
14. (b) Kinetin induces cell division.
16. (b) Cytokinin promotes RNA synthesis in nuclei after treatment
18. (b) Letham first synthesized cytokinin from corn milk.
4. (a) Wound hormone is also called as traumatic acid or necrohormone.
5. (a) Maleic hydrazide is a growth retardant which checks cell division.
7. (a) Morphactins are synthetic growth regulators which act in variety of ways on the natural regulation mechanism of plants.
8. (b) Morphactins have inhibitory efficient on the stem elongation. Increased concentration produces dwarfing in the plants.
11. (c) Gibberellins and ABA are antagonistic with each other.
12. (c) ABA inhibits the  $H^+|K^+$  exchange and promotes the leakage of maleic acid. The reduction of osmotically active solutes would render the guard cells flaccid and keep the stomatal pore closed.
13. (b) Absciscic acid (also called stress hormone) is a mildly acidic growth hormone which function as a general growth inhibitor by counteracting other hormones (auxin, gibberellin, cytokinin) or the reactions mediated by them. ABA induced bud dormancy, seed dormancy closure of stomata and stopage of cabial activity.
18. (d) The synthesis of absciscic acid is stimulated by drought, water logging and other adverse environmental condition. Therefore, it is also called as stress hormone.
19. (b) Absciscic acid stimulates senescence of leaves by causing destruction of chlorophyll and inhibition of protein and RNA synthesis.

### Ethylene

1. (a) Ethylene retards the flowering in most of the plants but increase flowering in pineapple in off season.
4. (a) Ethylene is gaseous hormone which stimulates transverse or isodiametric growth but retards the longitudinal one.
7. (d) Ethylene is a gaseous plant hormone and it is responsible for fruit ripening.
11. (d) Root development and root hair formation  $C_2H_4$ .
12. (a) Suitable combination of gases in atmosphere for fruit ripening is 80% ethylene ( $C_2H_4$ ) and 20%  $CO_2$ .
13. (d) As ethylene inhibits longitudinal growth but stimulates transverse growth.

### ABA and Other growth regulators

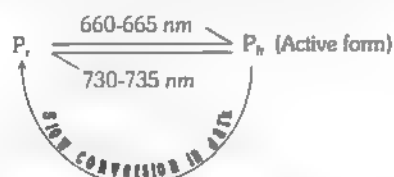
1. (d) Spray of absciscic acid causes very fast abscission of leaves, and also causes dormancy of buds and seeds.
2. (b) Because IAA, NAA and GA are growth promoters and ABA is growth inhibitor.
3. (d) Seed germination is limited and hence absciscic acid induces dormancy of seeds and buds.

### Photoperiodism and Vernalization

1. (d) Photoperiodism is the term to denote a biological response to changes in the ratio of light and darkness in a 24 hour cycle.
2. (a) In phototropism according to Cholodny Went theory, unilateral light produces more auxin and hence more growth on the shaded side resulting in bending.
4. (a) Phytochrome exists in two interconvertible forms. The red (660 nm), absorbing form *Pr* and far red (740 nm), absorbing from *Pfr*.
5. (d) Phytochrome is responsible for absorption of red and far red light and it is involved in red–far red light interconversion. According to Buttler in 1959, light absorbing pigment are called as phytochrome. These are proteinaceous substances in which coloured pigment is chromatophore.
8. (d) Phytochrome is chromoprotein (Photosensitive) photoreceptor, blue pigment protein complex, found in almost all flowering plants (angiosperms).
11. (a) If dark period of SDP is interrupted, the plant will not have flower because in SDP, dark period is critical and necessary for flowering.

12. (c) The stimulus of vernalization is known as vernalin. The stimulus of vernalization that induce flowering could be a particular gibberellin or a mixture of gibberellins. If GA is sprayed on the single gene dwarf plants, genetic dwarfism is overcome and plants become long e.g., maize, pea, etc.

14. (c) Phytochrome is an amorphous photoreceptor protein pigment. It exists in two states, i.e., phytochrome Red ( $P_r$ ) and phytochrome far-red ( $P_{fr}$ ).



It is considered that during the day  $P_{fr}$  form of the phytochrome is accumulated in the plant which is inhibitory to flowering in short-day plants but is stimulatory in long day plants.

16. (a) Photoperiodic stimulus is perceived by mature/old leaves.
20. (b) Flowering is induced by light temperature.
28. (b) Because in vernalized plant 'vernalin' substance is produced which is responsible for flowering.
29. (c) Phytochrome is bright blue or bluish green pigment which is similar to phycocyanin.
30. (b) In stratification apple, plum, seeds, are exposed in well aerated, moist condition under low temperature of  $0 - 10^\circ \text{C}$  for weeks or months.
32. (c) The effect of photoperiod on flowering was discovered by Garner and Allard at USA in 1920 in case of Maryland mammoth variety of Tobacco which is an SDP.
33. (d) *Florigen*. In the process of flowering, this hypothetical hormone is applied which is gibberellin in nature.
34. (d) In photoperiodism, photoreceptor pigment called phytochrome are in fully developed mature leaves which receive the stimulus of light.
35. (c) In SDP the dark period is critical and must be continuous. If this dark period is interrupted even with a brief exposure of red light, the short day plant will not flower.
36. (b) Since flowering can take place during any part of the year therefore the plant is not sensitive to photoperiod.
37. (a) Red light of 660 nm stimulates germination in positively photoblastic seeds.
38. (c) Phytochrome occurs in two i.e.,  $P_r$  (Red light) and  $P_{fr}$  (far red light) and both are interconvertible. It is considered that during day time  $P_{fr}$  form accumulates in plants which is inhibitory to flowering in SDP. During night  $P_r$  form accumulates in plants which is stimulatory to flowering.

43. (d) Long-day plant will be induced to flower only when the period of available light exceeds a given critical or limiting period. Wheat, poppy, oat, beet etc. are longday plants.

45. (c) Because two types of phytochrome is present in plants i.e.,  $P_{660}$  and  $P_{730}$ .

47. (a) Etiolation is depigmentation in leaf when plant is placed in dark for more than 36 hrs. Plants get etiolated in dark, because chlorophyll is not synthesized in darkness.

48. (a) Actual absorption spectrum of  $P_r$  is 660 which is not in answer so answer may be 640 nm.

52. (c) Day neutral plants – flowering in plants is not affected due to variation in photoperiod. (Day length and night length)

### Critical Thinking Questions

1. (a) During enlargement phase of growth new particles of cellulose are deposited between particles of the old wall, is known as intussusception.
3. (b) Phytohormones are biochemical substances which regulates physiology of the plants.
7. (b) Sometimes apical bud inhibits the growth of lateral buds, it is called apical dominance. By moving on a grass lawn apical buds are removed and apical dominance of grass is broken.
8. (b) The apex inhibits the growth of axillary bud is called apical dominance.
9. (d) Clinostat (= klinostat) is an instrument which can eliminate the effect of gravity and allow a plant to grow horizontally by slowly rotating it.
10. (c) Because cytokinins initiate and promote cell division actively in plants tissue and tissue culture.
11. (c) Accumulation of auxin at the apex of the plant, which is responsible for the phototropism movement so that plant cells are elongated.
12. (d) If phytochrome  $P_{660}$  is exposed to red-light, it changes to  $P_{730}$  and if  $P_{730}$  is exposed to far-red light, it changes quickly back to  $P_{660}$  because both are in interconvertible form.
14. (b) GA is sprayed on these single gene dwarf plants, genetic dwarfism is overcome and plants become long e.g., maize, pea.
16. (d) Ethylene is unique in that it found only in gaseous form, and accelerates ripening of fruits, leaves abscission and promotes senescence.
17. (c) Phytochrome is pigment which regulates growth and development like, photoperiodism, chloroplast development, leaf abscission and senescence etc.



## Assertion and Reason

1. (c) Application of GA can induce flowering in long day plants. It has no favourable effect on size of flower and fruit in certain plants. The genetically dwarf plants can be made tall by application of GA.
2. (b) The first selective herbicides to be discovered and used widely were 2,4-D and its derivatives. These compounds are very potent auxins. 2,4-D and 2,4,5-T destroy dicots weeds. They block their sieve elements and disturb mitosis. The plant is ultimately destroyed. Agent orange, which was used in the war in Vietnam as a defoliant is an effective mixture of free 2,4-D and the N-butyl ester of 2,4,5-T.
3. (a) Auxin is produced by shoot tip and acts as a growth promoter for apical bud and inhibit the growth of lateral buds. When a terminal bud is removed, the nearest axillary buds begin to grow and the plant branches rapidly. In case of mulberry plants, pruning is done to remove apical dominance and causes more branching of the main body of the plant.
4. (c) Nastic movements are non-directional movements in which the response is determined by the structure of the responsive organ and not the direction of the stimulus. "Touch" responses in *Mimosa* are an example of movements that do not necessarily occur towards or away from the stimulus. The movement is produced due to turgor changes in the cells of pulvinus or swollen area lying at the base of the petiole, pinnae and pinnules.
5. (c) Phytochrome is a receptor pigment present in leaves. They are responsible for flowering in plants. Phytochrome are two types  $P_r$  (Red light) and  $P_{fr}$  (far-red light)  $P_{fr}$  are responsible for flowering in LDP.
6. (a) Secondary roots and shoots are plagiotropic that is, they grow to a position at an oblique angle ( $45^\circ$ ) to the gravitational force. Root and stem branches lie at an angle other than  $90^\circ$  to the direction of gravity.
7. (e) The apical bud is not the only source of auxins. Young developing leaves also produce auxins and it has been shown that auxins from this source may inhibit lateral bud growth. When the apical bud is removed, the lateral buds sprout. However, if a paste of auxin is painted on the cut end of the decapitated shoot, the lateral buds remain inhibited, as if the apical bud is present.
8. (b) When cytokinins are added directly to the abscission layer, senescence of the zone is retarded. This delays the degradation of protein and chlorophyll of the plant parts and hence delays senescence. As they act as antisenescence, they act as antagonistic to ethylene which accelerate senescence.
9. (b) In most fruits the rate of respiration will undergo a sharp rise and then fall near the end of ripening. Kidd and West termed this phenomenon "climacteric rise". The climacteric acts as a trigger that sets in progress those changes that rapidly transform the fruit from an unripe to a ripe condition. Finally, application of ethylene to unripe fruit will bring on a premature climacteric and accelerate ripening.
10. (b) Stratification of seeds may affect the disappearance of inhibitors and the buildup of germination promoters such as the gibberellins and cytokinins. Natural stratification occurs when seeds shed in the fall are covered with cold soil, debris and snow. In artificial stratification, layers of seeds are alternated with layers of moistened *Sphagnum* sand or some other appropriate material are stored at low temperatures.
11. (c) If total growth is plotted against time, an S-shaped or sigmoid curve is obtained. It consists of four parts-lag phase, log phase, phase of diminishing growth and stationary phase. Growth is slow in the lag phase, rapid during log or exponential phase, slow again during the phase of diminishing growth. Growth stops completely during the stationary phase. Log phase is also called as grand phase of growth due to fast growth in this phase.
12. (c) It has been demonstrated that flowering in plant is more of a response to the dark period than to the light period. In short day plants, plants can flower in complete darkness if supplied with exogenous nutrients. Flowering is prevented in them if dark period below the critical level is interrupted by a flash of light. Interruption of light by dark inhibits flowering under normal photoperiods.
13. (a) Phototropism is a paratonic directional growth movement of curvature which is induced and determined by the direction of light stimulus. Shoots grow towards the source of light hence called positively phototropic while roots grow away from the source of light hence called negatively phototropic.
14. (c) Light energy become effective when it is absorbed by a pigment. These pigments are called phytochromes. It occurs in two forms namely  $P_r$  and  $P_{fr}$ . The two forms are interconvertible. The  $P_r$  form absorbs red light of 660 nm and changed to  $P_{fr}$ . The  $P_{fr}$  form absorb far red light of 730 nm and changed to  $P_r$ . The  $P_r$  form stimulates whereas  $P_{fr}$  form inhibit flowering.  $P_{fr}$  form of phytochrome is the active form. The  $P_r$  form is not considered to be active.
15. (c) Chalkhjian, working on floral initiation, coined the term florigen for the flowering hormone thought to be present in photoinduced leaves and plants. It is supposed that leaf prepare a special compound A on receiving  $CO_2$ . A on turn produces B in dark and is followed by formation of C (florigen). The florigen translocates from vegetative meristems to floral initiation.
16. (b) Many plants do not come to flower before they experience a low temperature. These plants remain vegetative during the warm season, receive low temperature during winter, grow further and then bear flowers and fruits. Vernalization is, therefore, a process of shortening of the juvenile or vegetative phase and hastening flowering by a previous cold treatment. The stimulus of vernalization is perceived only by the meristematic cells, e.g., shoot tip, embryo tips, root apex, developing leaves etc.
17. (a)

## Plant Growth and Development

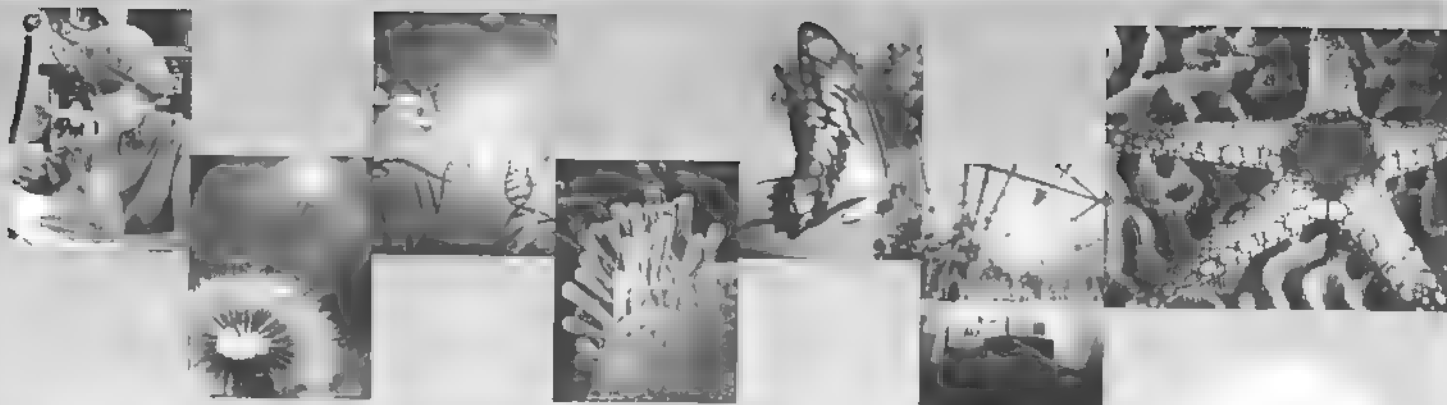
## Self Evaluation Test

1. Cold treatment of seeds is called [RPMT 2006]  
Or  
Seeds of winter varieties are benefited by this method [J & K CET 2010]  
(a) Vernalization (b) Stratification  
(c) Devernalization (d) Photophosphorylation
2. Crescograph was prepared by [BHU 2000, 01]  
(a) Bose (b) Strasburger  
(c) Went (d) None of the above
3. In callus culture, roots can be induced by the supply of [MP PMT 2013]  
(a) Auxin and no cytokinin  
(b) Higher amounts of auxin and lower amounts of cytokinin  
(c) Higher amounts of cytokinin and lower amounts of auxin  
(d) Auxin and cytokinin in equal amounts
4. Which of the following plant material is widely used in the preparation of culture medium  
(a) *Pinus longifolia* (b) *Cocos nucifera*  
(c) *Borassus flabellifer* (d) *Cycas revoluta*
5. Exponential growth in plants can be expressed as [Kerala PMT 2011]  
(a)  $L_t = L_0 + rt$  (b)  $L_t = L_0 e^{rt}$   
(c)  $W_t = W_0 e^{rt}$  (d)  $W_t = W_0 e^{rt}$
6. Which Hormone is responsible for vernalization [MP PMT 2011]  
(a) Florigen (b) Colchicine  
(c) Abscission (d) Vernalin
7. Antiauxin used in picking cotton balls is  
(a) NPA (b) 2-4D  
(c) TIBA (d) Both (a) and (c)
8. A substance which is used to stimulate the increase in size of the apple fruit is [NCERT]  
(a) Morphactin (b) Promalin  
(c) Ethylene (d) Ethapone
9. Storage sprouting of potato can be prevented by  
(a) IAA (b) Maleic hydrazide  
(c) Cytokinins (d) Gibberellins
10. A substance isolated from herring sperm DNA and named as 'kinetin' by [NCERT]  
(a) Miller (b) Skoog  
(c) Saltz and Strong (d) All the above

## Answers and Solutions

1	a	2	a	3	b	4	b	5	c
6	d	7	d	8	b	9	b	10	a

1. (a) The term vernalisation was coined by Lysenko to the method of accelerating the flowering ability of biennials or winter annuals, by exposing their soaked seeds to low temperatures for a few weeks
2. (a) It is more delicate instrument and gives magnification upto 10,000 times. It uses as a root auxanometer.
4. (b) Because liquid endosperm of *Cocos nucifera* possesses kinetin (cytokinin) growth hormone which is responsible for rapid cell division in culture medium.
8. (b) Promalin is a mixture of cytokinin-6-benzaldehyde,  $GA_4$  and  $GA_7$ . It is very active in stimulating increase in apple size particularly in red delicious apples.
9. (b) Maleic hydrazide : It is a growth retardant which checks cell division. So during seed storage this is applied for checking sprouting of potato tubers so that the importance of potato may not be lowered down.
10. (a) Isolation and identification of kinetin, (6-furfurylaminoprine) from nucleic acid preparations, was first reported by Miller (1956).



## Chapter

# 5.1

## Digestion and Absorption

Animals are not able to synthesise their own food, therefore they depend on ready-made food for their nutritional requirements. The term nutrition refers to the sum total of all the processes related with the conversion of the raw foodstuff into the stuff of the body to supply energy for different metabolic activities and also for the repair and growth. In other word we can define nutrition as the process by which an organism derives energy to work and other materials, required for growth and maintenance of the various activities of life.

**Food Intake :** Different organisms obtain food in different ways but carry out similar chemical reactions to utilize it. To take food, protozoans use pseudopodia, flagella or cilia; sponges and mussels, a current of water; Hydra, tentacles beset with stinging cells; planarians and earthworms, a muscular pharynx; flukes and leeches, oral sucker; insects and other arthropods, mouth parts of various kinds; and seastars and sea urchins, tube feet. Sharks capture prey with the jaws; frog and lizard with the tongue; birds with beaks of sorts; rabbit and hare use forepaws, lips and teeth; cattle, lips and teeth; carnivores, claws and teeth; giraffes, tongue; elephants, proboscis (trunk); humans, monkeys and apes use hands

### Digestion

The process by which complex food is converted into simplest food with the help of digestive enzymes (Hydrolytic enzymes) is called digestion. Hence process of digestion is a hydrolytic process.

#### Types of digestion

(1) **Intracellular :** When the process of digestion occurs within the cell in the food vacuole. Examples : Protozoa, Porifera, Coelenterata and free living platyhelminthes.

(2) **Extracellular :** When the process of digestion occurs outside the cell. Examples : Coelenterates and phylum platyhelminthes to phylum chordata.

### Digestive system of human

Digestion in vertebrates occurs in the digestive tract or alimentary canal. The various parts involved in digestion can be broadly grouped in two groups –

- (i) Digestive tract or alimentary canal
- (ii) Digestive glands

#### Digestive tract or alimentary canal

On the basis of the embryonic origin, the alimentary canal of vertebrates can be divided into three parts –

(1) **Fore gut / Stomodaeum :** Ectodermal. It includes buccal cavity / oral cavity, pharynx, oesophagus, stomach and small part of duodenum.

(2) **Mid gut / Mesodaeum :** Endodermal. It includes small intestine, and large intestine.

(3) **Hind gut / Proctodaeum :** Ectodermal. It includes anal canal and anus.

#### Parts of alimentary canal and its histology

##### Mouth

The mouth is a transverse slit bounded by two movable lips or labia, upper lip and lower lip. Upper lip has small ridges on the sides, a tubercle in the middle and a vertical groove (philtrum) above.

##### Vestibule

It is a narrow space between lips and gums in front and gums and cheeks on the sides. Its lining contains mucous glands. In the vestibule, a small median fold of mucous membrane, the superior labial frenulum, connects the middle of the upper lip to the gum and usually a similar but smaller inferior labial frenulum connects the middle of the lower lip to the gum.

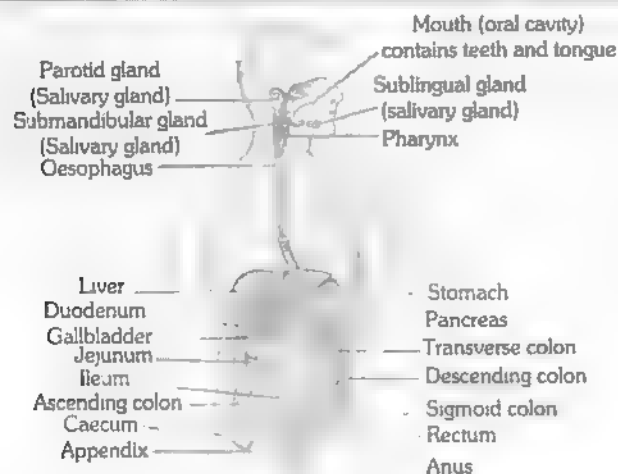


Fig : 5.1-1 Human Alimentary canal

**Buccopharyngeal cavity**

It includes anterior buccal cavity lined by stratified squamous epithelial cells and posterior pharyngeal cavity lined by columnar epithelial cells. It is distinguished into three regions. Pharynx is a vertical canal beyond the soft palate. The food and air passages cross here. Pharynx may be divided into three parts; Nasopharynx, Oropharynx and Laryngopharynx.

Main structures of Buccopharyngeal cavity are –

(1) **Palate** : The roof of buccal cavity is called Palate. In crocodiles and mammals horizontal shelf like processes of premaxilla and maxilla and the palatine bones of upper jaw fuse and form a secondary palate which separates the buccal cavity from nasal cavity. Palate is distinguished into three regions –

(i) **Hard palate** : Anterior, bony portion formed of maxilla and palatine bones in human and premaxilla, maxilla and palatine bones in rabbit. Hard palate has transverse ridges called palatine rugae. Such rugae or ridges are more developed in carnivorous mammals because their function is to firmly grip the food and prevent it from slipping out of the cavity.

(ii) **Soft palate** : Posterior soft part, made up of connective tissue and muscles.

(iii) **Vellum palati/uvula** : Posterior most part of soft palate, which hangs in the region of pharynx. It closes the internal nostrils during deglutition.

(2) **Palatine glands** : Numerous mucous glands. Chiefly present in soft palate, secrete mucus for lubrication.

(3) **Naso-palatine duct** : One pair, present in rabbit, extends from nasal passage to the buccal passage, contains Jacobson's organ concerned with olfaction.

(4) **Vibrissae** : A tuft of hairs on upper lip of rabbit.

(5) **Hare-cleft** : A cleft on the upper lip of rabbit, which makes it bilobed.

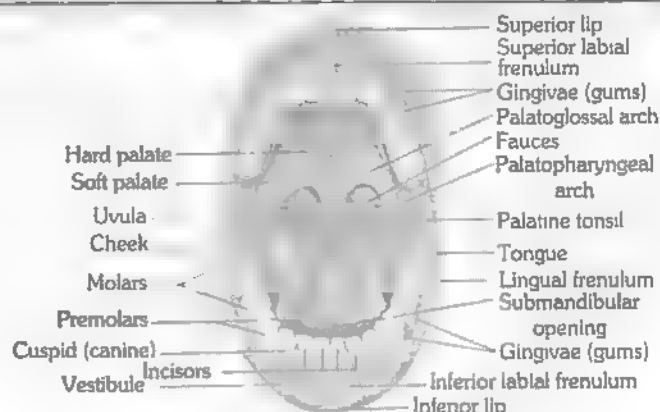


Fig : 5.1-2 Structures of the Oral cavity

(6) **Tongue (linguae)** : Ectodermal, single, pinkish, oval, elongated highly muscular (mesodermal) and protrusible present on the floor of buccopharyngeal cavity. The cells present are stratified squamous epithelial cells. A furrow termed the sulcus terminalis divides the oral part and pharyngeal part of the tongue. The limbs of the sulcus terminalis run laterally and forward from a median pit, named the foramen caecum.

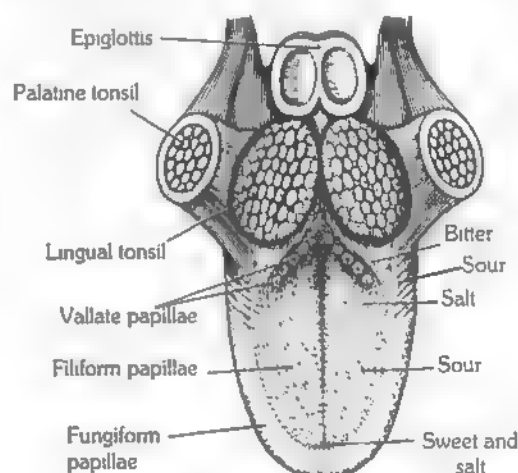


Fig : 5.1-3 Locations of papillae and areas of taste on the tongue

Posterior part of tongue (endodermal) is attached with hyoid, middle one with the floor of buccopharyngeal cavity with the help of frenulum linguae and anterior part is free. The tongue is provided with two specialized structures viz. lingual papillae and lingual glands or Weber's gland. Lingual glands are the mucous glands, which secrete mucus. Lingual papillae are numerous, minute projections chiefly present on the dorsum of the tongue. All these lingual papillae can be grouped as simple lingual papillae and taste papillae. Taste papillae are of the following types –

(i) **Circumvallate** : Circular, largest 8-12 in number, present in the posterior part of the tongue extending from one side to another. They possess taste buds. These are the largest of all the papillae.

(ii) **Fungiform** : Mushroom shaped (Fungi – shaped), numerous, present at the anterior margins and tip of the tongue. They have 200 taste buds.

(iii) **Foliate** : Leaf like flat, less 8-10 in number, present at the posterior margin of the tongue. They are absent in human and found in rabbit.

(iv) **Filiform** : Conical shaped, smallest and most numerous distributed throughout tongue. They are without taste buds.

Hence, in human taste is recognized with the help of circumvallate and fungiform taste papillae. In man the anterior end of tongue feels sweet taste, posterior part feel bitter taste, sides feel sour taste and a small part behind the anterior end feel salty taste.

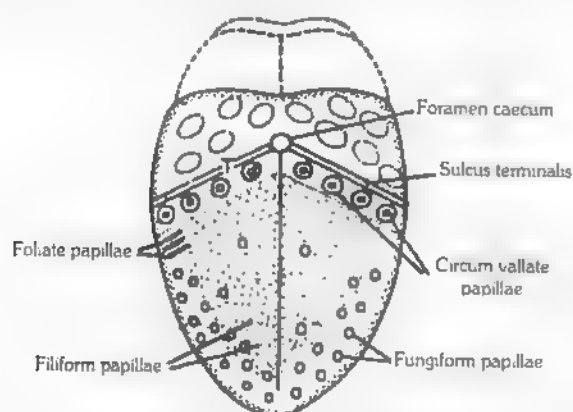


Fig : 5.1-4 Dorsal surface of human tongue, showing three kinds of papillae and some other associated structures

**Functions of tongue** : Important function of tongue are as follows –

- (i) Acts as universal toothbrush, as it helps in tooth cleaning.
- (ii) Helps in speaking.
- (iii) Helps in deglutition.
- (iv) Helps in mixing saliva with food.
- (v) Acts as a curry comb in many animals, hence help in body cleaning.
- (vi) Helps in taste detection.
- (vii) In dog helps in regulation of body temperature. The phenomenon is called as “Panting”.
- (viii) In frog and other animals, it helps in prey capturing

(7) **Teeth** : Teeth is a living structure. On the basis of embryonic origin, teeth in vertebrates are of following two types –

(i) **Horny/ectodermal/epidermal/false teeth** : The teeth which develops only from ectoderm. Examples – Cyclostomes, tadpole larva of frog, prototherian mammals etc.

(ii) **True teeth** : The teeth which develops from both ectoderm and mesoderm. Examples – Fishes, amphibians, reptiles, eutherian mammals etc

**Differentiation of teeth** : Morphologically, teeth can be distinguished as homodont or heterodont.

(i) **Homodont** : When all the teeth are structurally and functionally similar. Examples – Vertebrates except metatherian and eutherian mammals.

(ii) **Heterodont** : When the teeth are different in structure and functions. They are distinguished into four types incisors, canines, premolars and molars. Examples – metatherian and eutherian mammals.

(a) **Incisors** : These are the front teeth borne by the premaxillae in upper jaw and tips of dentaries in lower jaw. They are single-rooted monocuspid and long, curved and sharp-edged. They are adapted for cutting or cropping and biting.

(b) **Canines** : There is one pointed canine in each maxillary of upper jaw and each dentary of lower jaw next to the incisors. They are meant for piercing, tearing and offence and defence. They are single rooted and monocuspid.

(c) **Premolars** : They have one root (only in upper first PM two roots) and two cusps (bicuspid). They are meant for crushing, grinding and chewing.

(d) **Molars** : They have more than two roots (upper molars have three roots and lower molars have two roots) and 4 cuspid.

**Attachment of teeth** : On the basis of attachment of teeth at their bases with the jaw bones, teeth can be differentiated into –

(i) **Acrodon** : Teeth are attached to the free surface or summit of the jaw bone, as in a shark or frog. Such teeth are apt to break off easily but are replaced

(ii) **Pleurodon** : In this condition, common in urodeles and lizards, teeth are attached to the inner side of jaw bone by their base as well as one side.

(iii) **Thecodont** : Such teeth are characteristic of mammals. Teeth have well developed roots implanted in deep individual pits or sockets called alveoli or theca, in the jaw bone. These type of teeth also present in crocodilians, fossil toothed bird (*Archaeopteryx*).

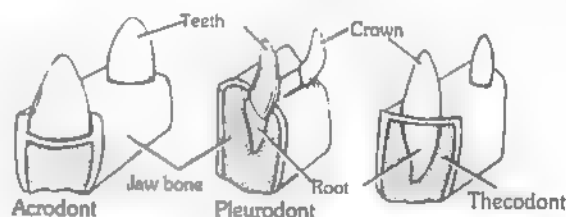


Fig : 5.1-5 Methods of attachment of teeth on jaws

**Succession of teeth** : According to their replacement (succession), teeth can be divided into 3 categories: polyphyodont, diphyodont and monophyodont.

(i) **Polyphyodont** : In lower vertebrates, teeth can be replaced an indefinite number of times during life. e.g., – Fishes, amphibia, reptalia.

(ii) **Diphyodont** : In most mammals teeth develop during life in two successive sets, a condition known as diphyodont. Teeth of the first set are known as deciduous teeth or milk teeth or lacteal teeth whereas the second set is called permanent teeth.

(iii) **Monophyodont** : In some mammals such as platypus, marsupials, moles, sirenians, toothed whale etc. only one set of teeth develops known as monophyodont condition.

#### Types of cheek teeth

(i) **Bunodont** : Crown with small, blunt and round cusps as in man, monkey, pig etc. found in mixed diet mammals.

(ii) **Secodont** : With sharp cutting edges for tearing flesh as in carnivores

(iii) **Lophodont** : Only one cusp is present with transverse ridges called lophos, e.g., Elephant.

(iv) **Selenodont** : With vertical crescentic cusps as in grazing mammals like cow, sheep and goat. Selenodont teeth are two types –

(a) **Brachyodont** : Normal low crowned selenodont teeth with large roots are termed brachyodont. e.g. Ground squirrel, cattle.

(b) **Hypsodont** : In large grazing mammals teeth are elongated, prism shaped with high crown and low roots. e.g. Horse.

**Structure of teeth** : Teeth divided into three parts –

(i) **Root** : Inner most, attached to the bone with the help of cement (hyaluronic acid).

(ii) **Neck** : Middle, small, covered with gum. Gum provides strength to the teeth.

(iii) **Apex or crown** : External exposed part of teeth. Longest part, white in colour.

A small cavity present inside teeth called as pulp cavity or dentine pulp cavity. It contains blood vessels, lymphatic vessels, nerve fibres, connective tissue etc. and provides nutrition to odontoblast cells or osteoblast cells. The odontoblast cells are mesodermal in embryonic origin forming immediate covering of the pulp cavity. The cells secrete dentine/ivory. Bulk of tooth in a mammal is formed of dentine. Dentine is a layer of inorganic substances (62-69%), which surrounds the odontoblast cells. It is mesodermal in origin. Enamel, secreted by Ameloblast/Enameloblast cells, forms the outermost covering. It is ectodermal and made up of 92% of inorganic substances, hence considered as hardest part of the body. The inorganic substances present are  $[Ca_3(PO_4)_2, Ca(OH)_2, H_2O]$  Calcium phosphate (85%), Calcium hydroxide and Calcium Carbonate. Cement/Cementum attaches the tooth root to the bone

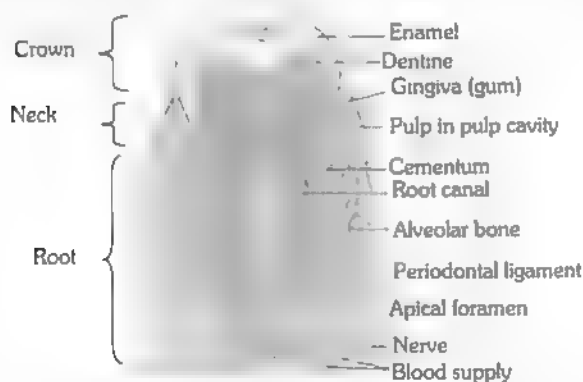


Fig : 5.1-6 Structure of tooth

**Dental formula** : Each mammalian species is characterized by its own specific dentition with a definite number and arrangement of teeth. Hence, dentition is of taxonomic importance. It is expressed by a dental formula as below –

$$\text{Rabbit : } I \frac{2}{1}, c \frac{0}{0}, pm \frac{3}{2}, m \frac{3}{3} = \frac{8}{6} \times 2 = 28 \text{ or briefly,}$$

$$\frac{2033}{1023} = \frac{2+0+3+3}{1+0+2+3} \times \frac{2}{2} = \frac{16}{12} = 28$$

(I = incisors; c = canines; pm = premolars; m = molars)

Table : 5.1-1 Dental formulae of some common mammals

Horse and pig	$\frac{3 \ 1 \ 4 \ 3}{3 \ 1 \ 4 \ 3} \times 2 = 44$	Cat	$\frac{3 \ 1 \ 3 \ 1}{3 \ 1 \ 2 \ 1} \times 2 = 30$
Dog	$\frac{3 \ 1 \ 4 \ 2}{3 \ 1 \ 4 \ 3} \times 2 = 42$	Squirrel	$\frac{1 \ 0 \ 2 \ 3}{1 \ 0 \ 1 \ 3} \times 2 = 22$
Lemur	$\frac{2 \ 1 \ 3 \ 3}{2 \ 1 \ 3 \ 3} \times 2 = 36$	Rat	$\frac{1 \ 0 \ 0 \ 3}{1 \ 0 \ 0 \ 3} \times 2 = 16$
Man (adult set)	$\frac{2 \ 1 \ 2 \ 3}{2 \ 1 \ 2 \ 3} \times 2 = 32$	Elephant	$\frac{1 \ 0 \ 0 \ 3}{0 \ 0 \ 0 \ 3} \times 2 = 14$
Cow	$\frac{0 \ 0 \ 3 \ 3}{3 \ 1 \ 3 \ 3} \times 2 = 32$	Human set (milk set)	$\frac{2 \ 1 \ 0 \ 2}{2 \ 1 \ 0 \ 2} \times 2 = 20$

### Oesophagus (food tube)

(1) **Morphology** : Single, ectodermal, dorsal to trachea, approximately 25 cm long. passes through thoracic cavity and opens into stomach present in abdominal cavity. Oesophagus anteriorly opens into pharynx through gullet and posteriorly into stomach through cardiac orifice.

(2) **Histology** : Serosa is absent but outermost layer of connective tissue is called as tunica adventitia. Muscular layer are striated/voluntary in anterior region and unstriated/involuntary in posterior part. The epithelial lining is made up of non-keratinized stratified squamous epithelial cells. Goblet cells are present.

Oesophagus lack digestive glands but multicellular glands are found, which extends upto submucosa. Due to the presence of these submucosal mucous glands, submucosa of oesophagus is thickest than other parts of alimentary canal.

**Function** : Conduction of food.

### Stomach

(1) **Structure** : Single oval, elongated, unlobed present within abdominal cavity below diaphragm. It consists of three parts as cardiac/fundic (anterior), corpus/body (middle, chief part) and pyloric (posterior part) in human, whereas in rabbit stomach is bilobed and consists of three parts as cardiac (Anterior), fundic (middle, chief part) and pylorus (posterior). Two types of valves are present in the stomach viz. Cardiac sphincter valve between oesophagus and stomach and pyloric sphincter valve between stomach and duodenum. In new born baby cardiac sphincter is much less developed that is why regurgitation of gastric contents is very common. Inner surface of stomach is raised into numerous longitudinal folds called gastric rugae. In case of ruminant mammals (cud chewing mammals) oesophagus consists of only skeletal or voluntary muscles.

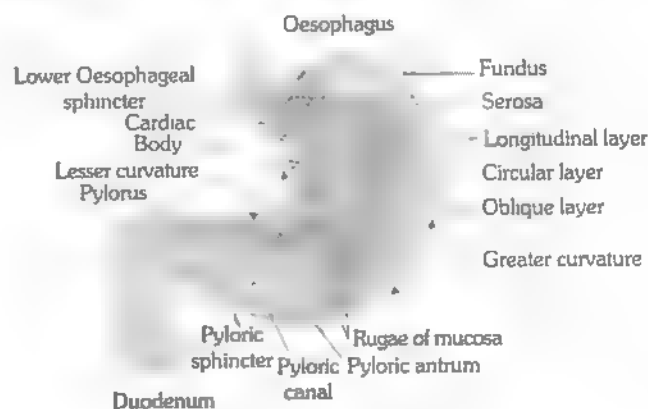


Fig : 5.1-7 Human Stomach

(2) **Histology** : Outermost layer is serosa. Muscular layer is three layered with outer longitudinal, middle circular and inner oblique. Muscles are involuntary and unstriated. Epithelial lining is made up of simple columnar epithelial cells and specialized cells present in the gastric glands. The nomenclature of gastric glands is according to the parts of the stomach. Various types of gastric glands and the cells present in them are as follows –

(i) **Anterior part** : Cardiac gastric glands in rabbit and human. Cells present are mucous neck cells secreting mucous.

(ii) **Middle part** : Fundic gastric/Main gastric glands in rabbit and corpus in human has at least four distinct types of cells –

(a) **Peptic or zymogenic or chief or central cells** : Secretes two digestive proenzymes pepsinogen and prorennin.

(b) **Oxyntic or parietal cells** : Secretes HCl and castle's Intrinsic factor required for the absorption of vitamin B<sub>12</sub>. Hyperacidity is abnormally high degree of acidity due to the secretion of large quantity of HCl i.e. gastric juice.

(c) **Mucous neck cells** : Secretes alkaline mucous.

(d) **Argentaffin cells or Kultchitsky or enterochromaffin cells** : Responsible for the secretion of vasoconstrictor serotonin.

(iii) **Posterior part** : Pyloric gastric glands in rabbit and human-cells are mucous neck cells secreting mucous and some cells, called "gastrin" or "G" cells, secrete a hormone, named gastrin, which increases the motility of gastric wall and stimulates gastric glands for active secretion.

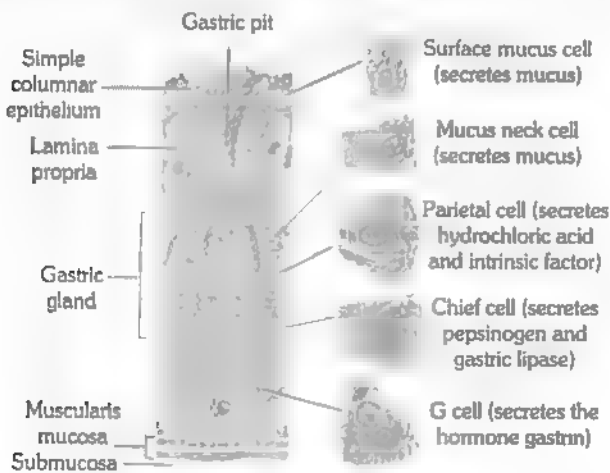


Fig : 5.1-8 L.S. Gastric gland

#### Functions

- (1) Storage of food.
- (2) Trituration or churning of food to mix with gastric juice.
- (3) Functions of gastric juice (discussed along with gastric juice).

**Stomach of ruminants (cud-chewing mammals)** : The stomach of cattles have four parts, as rumen (paunch), reticulum(honeycomb), omasum (psalterium) and abomasum (rennet). Some authors believe that first three chambers are parts of

the oesophagus, the fourth chamber is the real stomach secreting HCl and enzymes. The embryological studies have proved that all the chambers are parts of the real stomach. Camel and deer lack omasum. Reticulum is the smallest part and its cells are provided with water pockets for the storage of metabolic water.

In the rumen, food undergoes mechanical and chemical breakdown. Mechanical breakdown results from through churning brought about by muscular contractions and aided by cornified surface of villi. Chemical breakdown is caused by symbiotic microorganisms (bacteria and ciliates) that release enzyme cellulase, which act on cellulose and simplify it into short-chain fatty acids, such as acetic acid, butyric acid, propionic acid. This is called microbial digestion.

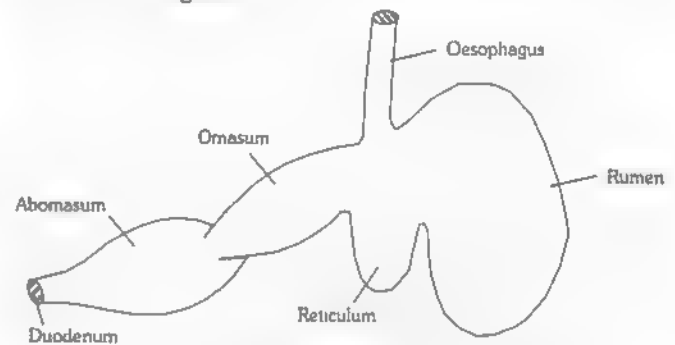


Fig : 5.1-9 The compound stomach of a ruminant

#### Small intestine

(1) **Structure** : Endodermal, longest part of alimentary canal present in the abdominal cavity, supported by a peritoneal membrane called mesentery. Wall of jejunum and ileum has circular or spiral internal fold called fold of kerckring or valvulae conniventes. Also numerous finger like projection called villi project from the wall of lumen, increasing internal surface area about ten time. The distal end of ileum leads into the large intestine by ileo-caecal valve in man but in rabbit sacculus rotundus and ileo-coecal valve both are present.

(2) **Parts** : It is approximately 3 metres in human. It is divisible into three parts duodenum, jejunum and ileum.

Table : 5.1-2 Parts of small intestine

Duodenum (Proximal part)	Jejunum (Middle part)	Ileum (Posterior part)
25 cm. Long	About 1 m long and about 4 cm. wide.	About 2 m long and about 3.5 cm. wide.
Forming U-shaped loop before leading to jejunum, pancreas lies in the loop.	Wall is thicker and more vascular.	Wall is thinner and less vascular.
	Villi thicker and tongue-like.	Villi thinner and finger-like.
	Plicae best developed.	Plicae less developed.
	Peyer's patches are lacking.	Peyer's patches are present.

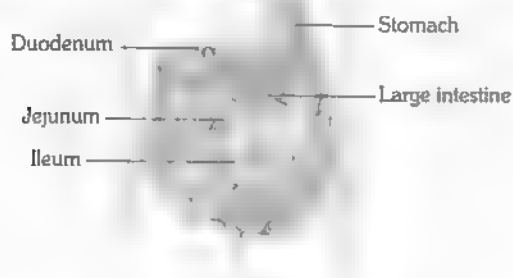


Fig : 5.1-10 Human intestine

(3) **Histology** : Serosa is the outer most covering. Muscular layer is generalized with involuntary, unstriated muscles. The cells present in the epithelial lining are simple columnar epithelial cells, which are brush- bordered i.e. provided with villi and microvilli to increase the surface area. The folds present are longitudinal and are called folds of kerckring or valvulae conniventes. Goblet cells secrete mucous. Peyer's patches are the oval, rounded masses of lymphatic tissue present in between lamina propria and epithelial lining. They produce lymphocytes. Brunner's glands or Duodenal glands are the multicellular mucous glands present in the submucosa of duodenum only. They secrete mucous. In addition there are also found granular argyrophil cell.

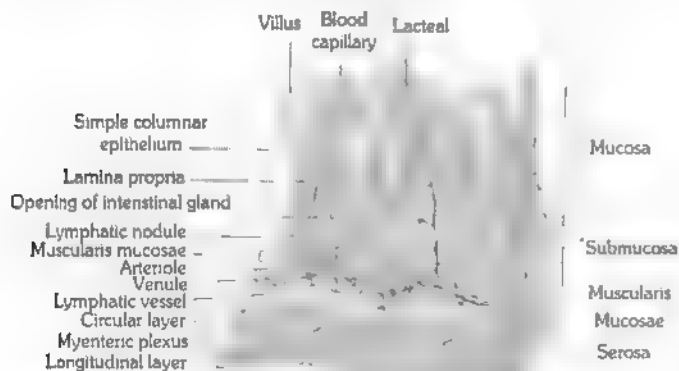


Fig : 5.1-11 Three dimensional view of layers of small intestine showing villi

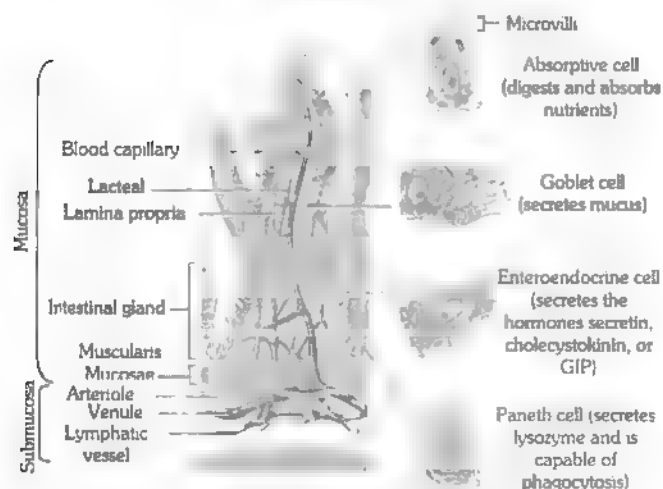


Fig : 5.1-12 Enlarged villus showing located, capillaries intestinal glands and cell types

(4) **Glands of small intestine** : Various glands found in small intestine. Each gland has three types of cells : (1) Undifferentiated epithelial cell (2) Zymogenic cell (paneth cell) and (3) Argentaffin (Enterochromaffin cell).

Table : 5.1-3 Glands of small intestine

Brunner's glands	Peyer's patches	Crypts of Lieberkuhn
Found in duodenum only	These are lymph nodules	Known as intestinal gland.
Mucus secreting gland as so known as mucus gland	They produce lymphocytes	Found in duodenum and ileum only.
	Lymphocytes are phagocytic in nature which destroy harmful bacteria	Secrete succus entericus i.e. intestinal juice.
		Formed by folding of lamina propria.

**Function** : Digestion and absorption of food.

#### Large intestine

The name large intestine is due to large diameter (4-6 cm).

(1) **Structure** : Endodermal, approximately 1.5-1.75 metre long.

(2) **Parts** : They are following –

(i) **Caecum** : Spirally coiled 6 cm long in human and 45 cm long in rabbit. Its posterior end is present as a blind sac in abdominal cavity called vermiform appendix. Vermiform appendix is vestigial but contains lymphatic tissue. Caecum in human is concerned with passage of food whereas in rabbit it is concerned with cellulose digestion and conduction of food.

(ii) **Colon** : Single endodermal approximately 1.3 m long in human distinguished into four limbs as ascending, transverse, descending and pelvic or sigmoid limb. Colon posses two specialized structures as Taeniae coli (present in the middle of colon) and Haustra, (dilated sac-like or pockets like structures surrounding taeniae). Colon is concerned with absorption of water of undigested food, 5%, salts, vitamins etc. hence concerned with faeces formation. Colon bacteria also synthesized vit.  $B_{12}$  and K.

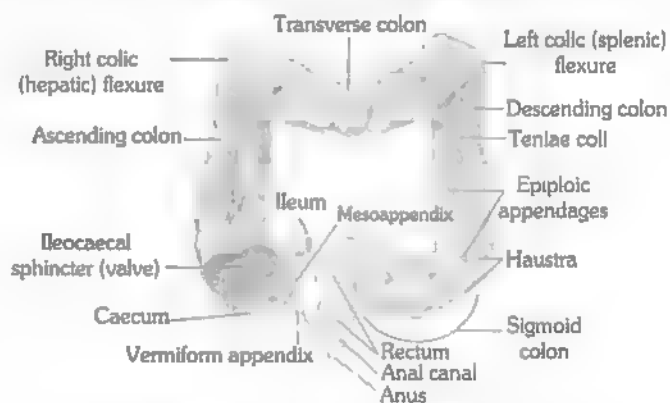


Fig : 5.1-13 Anterior view of large intestine showing major regions

(iii) **Rectum** : Single small dilated sac like in human whereas large beaded in rabbit. It is concerned with storage of faeces. Rectum has strong sphincter muscle in its wall. The sphincter keeps the canal as well as anus, closed when not used for defecation.



(iv) **Function** : Absorption of water from undigested food.

**Anal canal and anus** : Anal canal connects rectum with anus and it is about 3 cm. long. Anus is the terminal inferior opening of alimentary canal, which is guarded by an internal involuntary sphincter and an external voluntary sphincter.

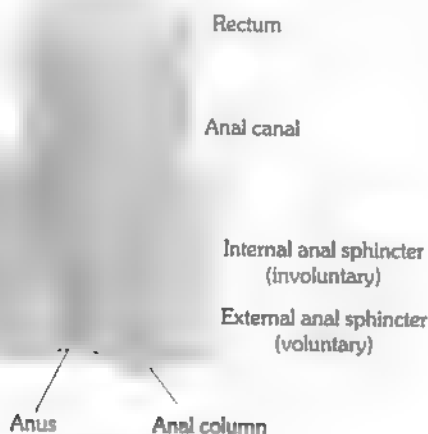


Fig : 5.1-14 Frontal section of anal canal

### Digestive glands

The various types of digestive glands present in mammals are salivary glands, gastric glands, intestinal glands, pancreas and liver. The digestive glands secrete digestive juices. Parasympathetic nervous system increases the secretion of digestive juice whereas sympathetic nervous system decreases it.

(a) **Salivary glands** : The three pairs of salivary glands present in humans are as follows –

(1) **Parotid** : One-pair, largest salivary gland present below pinna. A stenson's duct arises from each gland, opening in vestibule between the 2<sup>nd</sup> molar teeth of upper jaw and cheeks. Parotid glands secrete enzymes. Viral infection of parotid glands causes "Mumps" (by paramyxo virus).

(2) **Sub-mandibular / sub-maxillary** : One-pair, present at the junction of upper and lower jaw in cheek region. A wharton's duct arises from each gland and opens on lower jaw. These are seromucous glands.

(3) **Sub-lingual** : One-pair, present in the floor of buccopharyngeal cavity. These are mucous glands 6-8 ducts, called ducts of rivinus or Bartholin's duct arises from these glands and opens below tongue on the floor of buccopharyngeal cavity.

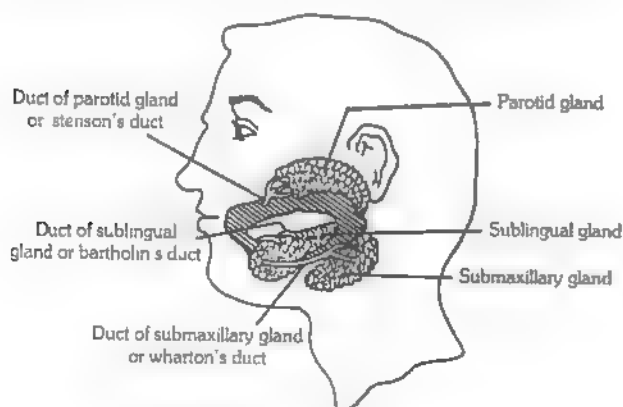


Fig : 5.1-15 Location of salivary glands in man

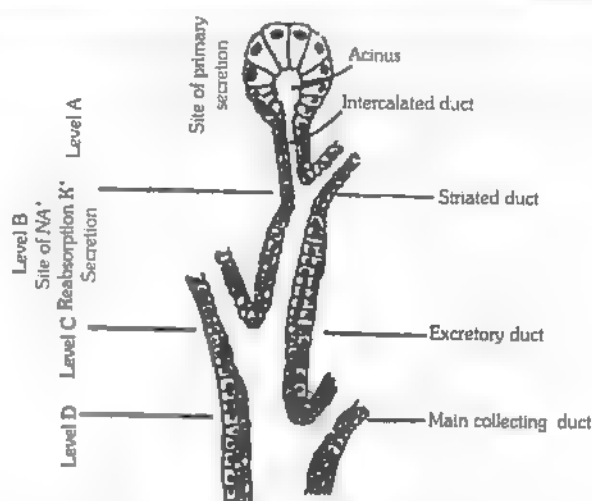


Fig : 5.1-16 An acinus of salivary gland

**Saliva / salivary juice** : The secretion of salivary glands is called saliva or salivary juice. Some of the characteristics are as follows –

- (1) Amount : 1.0-1.5 litre/day
- (2) Chemical nature : Slightly acidic.
- (3) pH : 6.3 – 6.8
- (4) Control of secretion : Autonomic reflex (parasympathetic nervous system increases salivation while sympathetic nervous system inhibit secretion.)
- (5) Chemical composition : Water (99.5%), mucous (acts as lubricant), salts ( $\text{NaCl}$ ,  $\text{NaHCO}_3$  etc.), enzymes (ptyalin, lysozyme) etc.

**Functions** : Salivary juice and its enzymes –

- (1) Makes the medium slightly acidic for the action of its enzyme.
- (2) Help in taste detection, deglutition, speaking etc.
- (3) Starch  $\xrightarrow[\text{(Salivary amylase)}]{\text{Ptyalin/Diastase}}$  Maltose + Isomaltose + Limit dextrin.

- (4) Bacteria (living)  $\xrightarrow{\text{Lysozyme}}$  Bacteria killed.

**Gastric glands** : There are approximately 35 million of gastric glands present in human stomach and grouped into three categories as already described along with stomach. The gastric gland secretes gastric juice.

### Gastric juice

- (1) Amount : 2-3 liters/day.
- (2) Chemical nature : Highly acidic
- (3) pH : 1.0 – 3.5 (due to presence of  $\text{HCl}$ )
- (4) Control of secretion : By gastric hormone.
- (5) Chemical composition : Water (99%), mucous, inorganic salts, castle's intrinsic factor,  $\text{HCl}$  (0.5%, conc.) and enzymes prorennin and pepsinogen and gastric lipase.

**Functions of gastric juice and its enzymes**

- (1) Inactivates the action of ptyalin.
- (2) Makes the medium acidic for the action of gastric enzymes.

(3)  $HCl$  kills micro organisms.

(4)  $HCl$  kills the living organism (prey etc.) if ingested.

(5) Pepsinogen (inactive)  $\xrightarrow{HCl}$  Pepsin (active).

(6) Prorennin (inactive)  $\xrightarrow{HCl}$  Rennin (active).

(7) Proteins + Peptones  $\xrightarrow[pH-1.3]{Pepsin}$  Polypeptides +

Oligopeptides.

(8) Casein (milk protein)  $\xrightarrow[Ca^{2+}]{Rennin}$  Paracaseinate Above phenomenon

is called "curdling of milk".

(9) Lipids  $\xrightarrow[negligible \text{ in human stomach acts at } pH\ 4-6]{Gastric\ Lipase}$  Triglycerides +

Monoglycerides.

(10)  $HCl$  is antiseptic.

(11) It act as preservative.

**Lactose intolerance :** Among mammals, man alone takes milk even after becoming adult. In some humans, secretion of lactase decreases or ceases with age. This condition is called lactose intolerance. Lactose intolerant persons fail to digest lactose of milk. In their large intestine, lactose is fermented by bacteria, producing gases and acids

**Intestinal glands :** Intestinal glands in mammals is a collective name for crypts of Lieberkuhn (secretes alkaline enzymatic juice) and Brunner's glands (secretes mucous). Intestinal glands secrete intestinal juice.

#### Succus entericus (Intestinal juice)

(1) Amount : 1.5 – 2.0 l/day.

(2) Chemical nature : Alkaline.

(3) pH : 7.6-8.3

(4) Control of secretion : Nervous and hormonal (Enterocrinin Duocrinin etc.)

(5) Chemical composition : Water (99%), mucous, inorganic salts, enzymes etc.

#### Function of Intestinal juice and its enzymes.

(1) Inhibits the action of gastric enzymes.

(2) Makes the medium alkaline for the action of it's enzymes.

(3) Starch  $\xrightarrow{Amylase}$  Maltose + Isomaltose + limit dextrin.

(4) Maltose  $\xrightarrow[\alpha\text{-glucosidase}]{Maltase}$  Glucose + Glucose.

(5) Isomaltose  $\xrightarrow{Isomaltase}$  Glucose + Glucose.

(6) Lactose (milk sugar)  $\xrightarrow[\beta\text{-galactosidase}]{Lactase}$  Glucose + Galactose.

(7) Sucrose (cane sugar)  $\xrightarrow[\beta\text{-fructosidase}]{Sucrase / Invertase}$  Glucose +

Fructose.

(8) Polypeptides + Oligopeptides  $\xrightarrow[Amino-peptidase]{Erepsin}$  Amino acids.

(9) Trypsinogen (inactive)  $\xrightarrow{Enterokinase}$  Trypsin (active).

(10) Lipids  $\xrightarrow{Lipase}$  Fatty acids + Glycerol + Monoglycerides.

(11) Phospholipids  $\xrightarrow{Phospholipase}$  phosphorous + Fatty acids + Glycerol + Monoglycerides.

(12) Organic phosphate  $\xrightarrow{Phosphatase}$  Free phosphate.

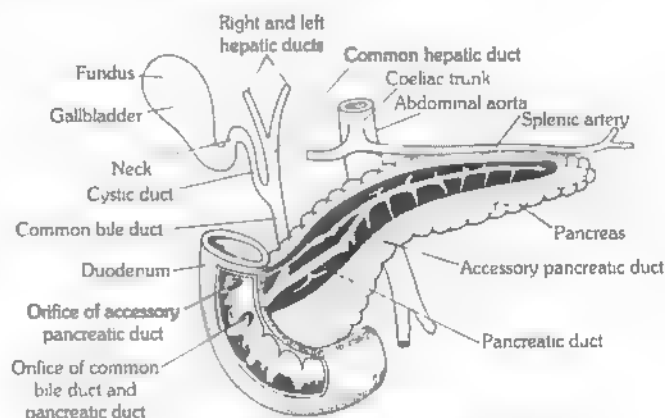
(13) Nucleic acid  $\xrightarrow{Polynucleotidase}$  Nucleotides.

(14) Nucleosides  $\xrightarrow{Nucleosidase}$  Nitrogenous bases.

**Pancreas :** Single, endodermal, flat, leaf-like yellowish, heterocrine (mixed) gland, present between the ascending and descending limb of duodenum and opens into duodenum through pancreatic duct. It can be divided into following parts –

**Exocrine :** It is the major part (about 99%) of pancreas. The exocrine tissue of the pancreas consists of rounded lobules (acini) that secrete an alkaline pancreatic juice. The juice is carried by the main pancreatic duct, also called duct of Wirsung, into the duodenum through the hepatopancreatic ampulla (ampulla of Vater). An accessory pancreatic duct, also named duct of Santorini, may sometimes lead directly into the duodenum.

**Endocrine :** Minor part (1% only) also called as islets of Langerhans scattered in the exocrine part. It consist of four various type of cells, as  $\alpha$ (A) cells,  $\beta$ (B) cells,  $\delta$ (D) cells and F or PP cells.  $\alpha$ -cells secrete glucagon hormone,  $\beta$ -cells secrete insulin hormone and  $\delta$  cells secrete somatostatin. The PP or F-cells secrete pancreatic polypeptid hormone to control somatostatin. The secretion passes directly into blood.



**Fig : 5.1-17 The gallbladder and pancreas and their systems of ducts. Both empty into the duodenum, often by a common orifice**

#### Pancreatic juice

(1) Amount : 1-1.5 l/day

(2) Chemical nature : alkaline

(3) pH : 7.1-8.2

(4) Control of secretion : Hormonal and normal mechanism

Secretin hormones stimulate the production of more alkaline pancreatic juice but low in enzyme content. Pancreozymin or Cholecystokinin stimulates the production of enzyme rich pancreatic juice.

(5) Chemical composition : Water (99%), enzymes and salts.

#### Functions of pancreas and its enzymes

(1) The islets of Langerhans secrete insulin and glucagon hormones.

(2) The exocrine part of pancreas secretes pancreatic juice.

(3) Elastase : It act upon elastin protein.

(4) Trypsinogen  $\xrightarrow[\text{Intestinal juice}]{\text{Enterokinase of}}$  Trypsin.

(5) Trypsinogen  $\xrightarrow[\text{(Autocatalysis)}]{\text{Trypsin}}$  Trypsin.

(6) Chymotrypsinogen  $\xrightarrow[\text{Autocatalysis}]{\text{Trypsin}}$  chymotrypsin.

(7) Polypeptides + peptones  $\xrightarrow[\text{(Pancreatic protease)}]{\text{Trypsin}}$  Tripeptides + Dipeptides + Oligopeptides.

(8) Starch  $\xrightarrow[\text{(Pancreatic amylase)}]{\text{Amylopsin}}$  Maltose + Isomaltose + limit dextrin.

(9) Emulsified Lipids  $\xrightarrow[\text{(Pancreatic lipase)}]{\text{Steapsin}}$  Fatty acids + Glycerol + Monoglycerides.

(10) Nucleic acid  $\xrightarrow{\text{Nuclease}}$  Nucleotides + Nucleosides.

(11) Nucleic acid  $\xrightarrow{\text{Nucleosidase}}$  Purines + Pyrimidines.

(12) Polypeptides  $\xrightarrow{\text{Chymotrypsin}}$  Oligopeptides.

#### Liver

(1) **Structure** : The liver is largest and heaviest gland in the body. Its upper and anterior surfaces are smooth and curved to fit the under surface of the diaphragm; the posterior surface is irregular in outline. It consists of three lobes in frog: right, left and median; five lobes in rabbit: left lateral, left central, spigelian, right central and caudate; four lobes in man: right, left, quadrates and caudate lobe. It is divided into two main lobes : right and left lobes separated by the falciform ligament.

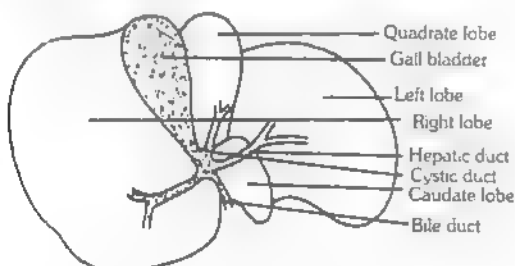


Fig : 5.1-18 Liver of man (ventral view)

A pear-shaped sac, the gall bladder is attached to the posterior surface of the liver by connective tissue. The right and left hepatic ducts join to form the common hepatic duct. The latter joins the cystic duct, which arises from the gall bladder. The cystic duct and

common hepatic duct join to form common bile duct or ductus cholidochus which passes downwards posteriorly to join the main pancreatic duct to form the hepatopancreatic ampulla (ampulla of Vater). The ampulla opens into the duodenum. The opening is guarded by the sphincter of Oddi. The sphincter of Boyden surrounds the opening of the bile duct before it is joined with the pancreatic duct. The basic structural and functional unit of the liver is the hepatic lobule.

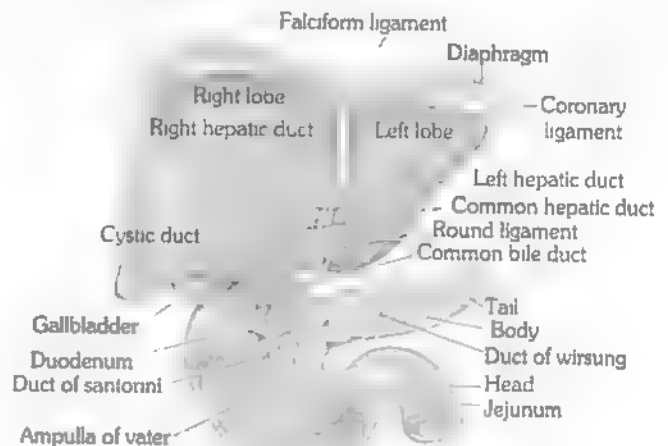


Fig : 5.1-19 Relation of Pancreas to the liver, gallbladder and duodenum

Each lobule is composed of plates of polyhedral, glycogen-rich cells, the hepatocytes, arranged radially around a central vein. Between the plates are radial blood sinusoids. At the periphery of the lobules, the branches of portal vein, hepatic artery, bile ducts, and lymphatics course together. A network of tubular spaces between the hepatocytes represents the bile canaliculi. At the periphery of the lobule the bile canaliculi empty into small hering's canals walled by cuboidal epithelium. These canals lead into bile ducts walled by columnar epithelium. The sinusoids are lined by incomplete endothelium with scattered phagocytic Kupffer cells, that eat bacteria and foreign substances

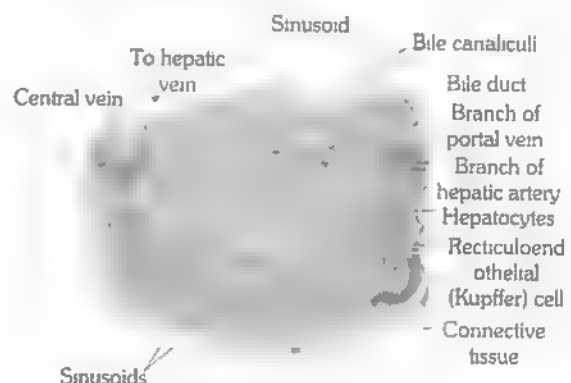
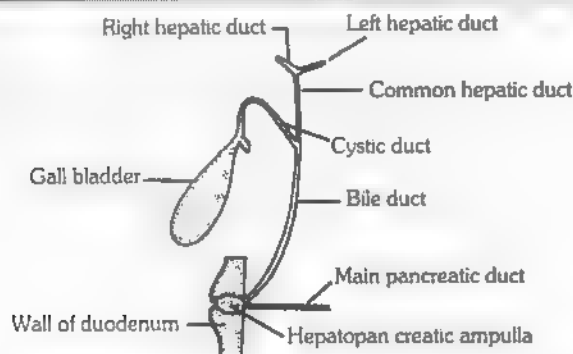
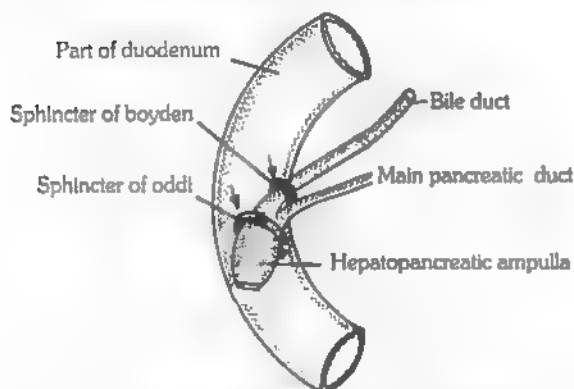


Fig : 5.1-20 Histology of a lobule

**Gall bladder** : The gall bladder is a slate-blue, pear-shaped sac connected with an supported from liver by a small omentum or ligament. Its distal part is called fundus, while the narrow part, continued as cystic duct, is called the neck.



**Fig : 5.1-21** Showing gall bladder, different ducts and hepatopancreatic ampulla



**Fig : 5.1-22** Showing sphincter of boyden and sphincter of oddi

**Functions of liver :** Liver, the largest gland of vertebrate body, is an essential organ, which performs many functions –

(1) It secretes bile which is a complex watery fluid containing bile salts (Na taurocholate and Na glycocholate), bile pigments (biliverdin and bilirubin), cholesterol, mucin, lecithin and fats etc. It breaks and emulsifies the fat

(2) In the liver, haemoglobin of the worn out erythrocytes breaks down to bile pigments bilirubin and biliverdin. The bile pigments are also converted in the bowel into stercobilin which colours the faeces.

(3) Excess quantities of carbohydrates (glucose) are converted to glycogen (Glycogenesis) in the presence of insulin in the liver cells, and stored therein.

(4) Glycogen is a reserve food material, which is changed into glucose (Glycogenolysis) and released into the blood at concentrations maintained constant by the liver. In this way, blood-sugar level is maintained under diverse dietary conditions.

(5) Under abnormal conditions, liver can convert proteins and fats into glucose by complex chemical reactions. Formation of this "new sugar" i.e. from non-carbohydrate sources, is called gluconeogenesis.

(6) If the level of blood-glucose rises beyond normal even after glycogenesis and catabolism, the excess glucose is converted into fat and stored in the liver. The process is termed lipogenesis.

(7) Amino acids resulting from protein digestion finally come into the liver from the intestine. They are partly released into the blood for distribution and protein synthesis, partly transaminated into other amino-acids and deaminated.

(8) In the embryo, red blood cells are manufactured by the liver. In the adult, liver stores inorganic salts of iron, copper and vitamin  $B_{12}$  (anti-anaemic factor) and thus helps in the formation of red blood cells and haemoglobin.

(9) Liver functions as a store-house for blood and regulates blood-volume.

(10) Fibrinogen, prothrombin and certain other blood coagulation factors are formed in the liver. Heparin is an intravascular anticoagulant that is stored in the liver.

(11) The plasma proteins serum albumin and serum globulin are synthesized by the liver from the amino acids.

(12) Liver synthesizes vitamin A from the provitamins A (carotenoid pigments). Liver cells also store fat-soluble vitamins A, D, E and K. Besides, it is the principal storage organ for vitamin  $B_{12}$ .

(13) The liver is the site of detoxification of different toxic substances either produced in the body or taken along with food.

(14) It is the main heat producing organ of the body.

(15) Kupffer cells in the liver sinusoids phagocytose and remove bacteria, worn-out blood elements and foreign particles.

(16) Liver is an important site of lymph formation.

#### **Bile/chole**

(1) Amount : 800-1000 ml daily. On the average about 700 ml.

(2) Source : Secreted by hepatic cells

(3) Storage site : Gall bladder

(4) Colour : Greenish-blue

(5) Chemical nature : Alkaline

(6) pH : 7.6–8.6

#### **Functions of bile**

(1) Emulsification of fats.

(2) Helps in absorption of fat-soluble vitamins.

(3) Increases alkalinity to make the medium suitable for enzymatic action.

(4) Elimination of heavy metals such as Cu, Hg, Zn etc.

(5) Elimination of excess of bile pigments.

(6) Stercobilin and urobilin (urobilin found in urine) is formed by bilirubin and biliverdin is responsible for colouration of faeces.

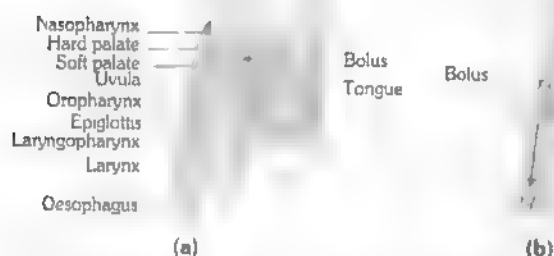
#### **Physiology of digestion**

The process of digestion involves following steps –

(1) **Ingestion** : It is the intake of food most of the animals capture the prey/food with the help of mouth or tongue.

(2) **Mastication** : The process occurs in the buccopharyngeal cavity of mammals with the help of teeth. During this process food is broken down into small pieces, which increases its surface area. In frog teeth are not meant for mastication but prevents the escape of prey from mouth.

(3) **Deglutition / swallowing** : The passage of food from buccopharyngeal cavity to oesophagus/stomach. In mammals bolus of the masticated food is formed in buccopharyngeal cavity which easily slides into oesophagus. It is a voluntary reflex mechanism. Peristalsis is alternative contraction and relaxation of circular and longitudinal muscles produces the wave of contraction due to which the food passes from front to backward direction in the lumen of alimentary canal. The phenomenon is called as peristalsis. Beside alimentary canal, it is also found in vas deference, ureter etc. Peristalsis is maximum in oesophagus and minimum in rectum



**Fig : 5.1-23 Deglutition (swallowing); (a) Position of structures before swallowing, (b) During the pharyngeal stage of swallowing**

Antiperistalsis is the peristaltic wave occurring in the reverse direction. It occurs in alimentary canal and results in vomiting. The phenomenon is called as "Regurgitation".

(4) **Digestion** : The process by which complex food is converted into simple food with the help of digestive enzymes. The process of digestion in mammals starts in buccopharyngeal cavity.

(i) **Digestion in buccopharyngeal cavity** : In buccopharyngeal cavity of mammals only starch is digested which is 5% of total food or 20-30% of carbohydrates.

(ii) **Digestion in stomach** : Chiefly proteins are digested in stomach

(iii) **Digestion in small intestine** : All three components (carbohydrates, proteins and fats) are digested in small intestine with the help of enzymes secreted by pancreas and intestinal glands.

(5) **Absorption** : Ingestion and digestion are the first two phases of the physiological processes occurring in the alimentary tract. The third phase is that of absorption by which the digested nutrients are absorbed through the wall of gut into blood.

(i) **Absorption from the mouth** : Normally, there is no absorption from the mouth, but a few drugs may be absorbed into the blood through the mucous membrane, if allowed to dissolve under the tongue, e.g., isoprenaline, glyceryl trinitrate.

(ii) **Absorption from the stomach** : In the stomach, absorption takes place to a limited degree. The only substances normally absorbed from the stomach are some water, glucose and considerable amounts of alcohol. These substances are absorbed through the walls of the stomach into the venous circulation. Although iron absorption takes place in the small intestine, it is dissolved out of foods most effectively in the stomach in the presence of HCl.

(iii) **Absorption from the small intestine** : The small intestine is the main absorptive organ. About 90% of the ingested foodstuffs are absorbed in the course of passage through the small intestine.

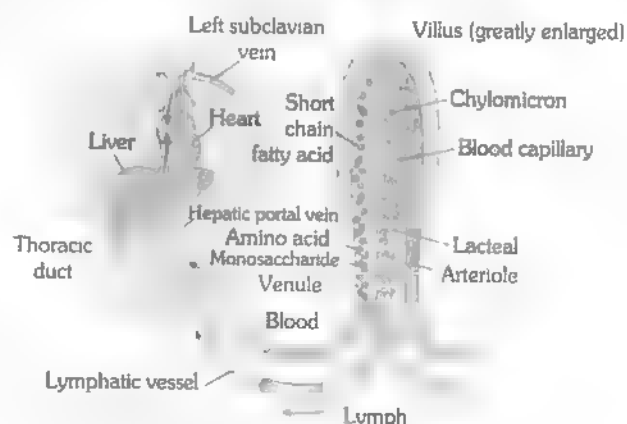
There are two general pathways for the transport of materials absorbed by the intestine; the veins of the hepatic portal system which lead directly to the liver; and the lymphatic vessels of the intestinal area, which eventually lead to the blood by way of the lymphatic system and the thoracic duct.

**Absorption of carbohydrates** : The products of carbohydrate digestion are absorbed from the intestine into blood of the portal venous system in the form of monosaccharides, chiefly the hexoses (glucose, fructose, mannose and galactose).

**Absorption of amino acids and protein** : It is probable that under normal circumstances the dietary proteins are almost completely digested to their constituent amino acids and that these end products of protein digestion are then actively transported from the intestine into the portal blood. Surplus amino acids are also withdrawn from portal blood by liver cells and deaminated into ammonia and keto acids. The ammonia is converted to urea and released into blood for excretion by kidneys, while the keto acids are converted to glucose or pyruvic acid and utilized for energy-production or for storage as glycogen and fat.

**Absorption of fats** : The dietary fat is digested, by the action of the pancreatic lipase present in the intestine, partially into glycerol and fatty acids and partially to split products such as monoacyl glycerols. These products of fat digestion enter the mucosal cells of the small intestine in the form of micelles, fatty acids and glycerol.

By the lacteals, the fat is carried to the cisterna chyli (meaning 'the receiver of the chyle') and then by the thoracic (lymph) duct to the left branchiocephalic vein, where it enters the blood. The lymph reaching the thoracic duct from the intestines contains an excess of fat giving it a milky appearance. It is called chyle. In this way, fatty acids and glycerol are eventually brought into the blood stream and so, by a circuitous route, to the liver. In the liver, they are reorganized and recombined to form human fat.



**Fig : 5.1-24 Movement of absorbed nutrients into the blood and lymph**

**Absorption of vitamins :** Water-soluble vitamins like members of B complex (except B<sub>12</sub>) and vitamin C readily diffuse across the walls of the intestine into the blood. The fat-soluble vitamins A, D, E and K are dissolved in micelles, which enter the mucosal cells of the intestine, by simple diffusion. The absorption of these fat-soluble vitamins is markedly decreased in the absence of bile.

(iv) **Absorption in large intestine :** About 100-200 ml. of the water of undigested food is absorbed in the colon. It helps in maintaining the body water level. Some amount of mineral salts and vitamins are also absorbed. The symbiotic bacteria (*E. coli*) present in the large intestine, converts the inactive vitamins into active forms (i.e., they synthesizes vitamins (vitamin B complex and vitamin K) which are absorbed.

(6) **Assimilation :** Conversion of absorbed food into active cytoplasm within cell is called as assimilation.

(7) **Faeces formation :** The phenomenon occurs in colon due to absorption of water, salts, minerals and vitamins. The peristalsis in colon also helps in faeces formation.

(8) **Egestion / defaecation :** The elimination of faeces from the alimentary canal is called egestion or defaecation. The faeces is waste matter discharged from the alimentary canal.

**Pseudo-rumination or coprophagy :** Animals swallows night faeces and recycle it through the gut to complete the digestion of cellulose and, making full use of their food. This habit is called coprophagy. Example – Rabbit.

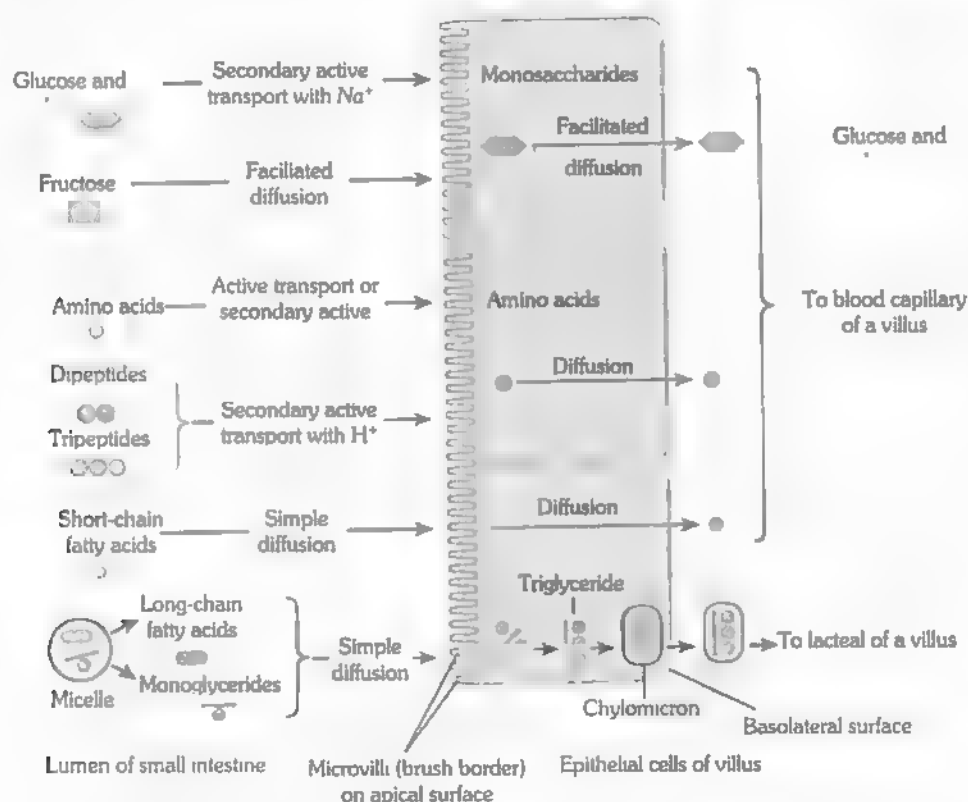


Fig : 5.1-25 Absorption of digested nutrients in the small intestine

Table : 5.1-4 Summary of physiology of digestion Major gastrointestinal enzyme in mammals

Name of gland	Name of digestive juice & optimum pH	Name of enzyme	Site of action	Substrates	Products
Salivary glands	Saliva (6.3 – 6.8)	Ptyalin Salivary amylase	Mouth	Starch, dextrins, glycogen	Dextrins, maltose, isomaltose and limit dextrin.
Gastric glands	Gastric Juice (1.3)	Pepsin	Stomach	Proteins, casein (Milk)	Peptones, paracasein (curd) Proteoses
		Rennin Gastric lipase	Stomach Stomach	Casein Fats	Paracasein Fatty acid and Glycerol.
Liver	Bile juice (7.6-8.6)	No enzymes	Duodenum	Fat	Makes the food alkaline, emulsifies fat and kills the harmful bacteria

Liver	Bile (7.6 – 8.6)	No enzyme but useful digestive juice, provides alkaline medium, stops the action of HCl Emulsifies fats and kills harmful bacteria.			
Pancreas	Pancreatic Juice (7.1 – 8.2)	Amylase/Diastase	Small intestine	Starch, dextrins, glycogen.	'Limits' dextrins, maltose, isomaltose.
		Trypsin	Small intestine	Proteins, Chymotrypsinogen (inactive) procarboxy peptidases (inactive) Fibrinogen (blood) Casein (milk)	Peptides, Chymotrypsin (active) carboxy peptidases (active) Elastase (active), Fibrin (clot) Paracasein (curd)
		Chymotrypsin	Small intestine	Peptones	Peptides
		Carboxypeptidases	Small intestine	Peptides	Smaller peptides and Amino acids
		Lipase / Steapsin	Small intestine	Triglycerides	Mono-glycerides, fatty acids
		DNAase RNAase	Small intestine Small intestine	DNA RNA	Deoxyribonucleotides Ribonucleotides
Intestinal glands	Intestinal Juice (7.5–8.3)	Enteropeptidase (enterokinase)	Small Intestine	Trypsinogen (inactive)	Trypsin (active)
		Aminopeptidase	Small Intestine	Peptides	Smaller peptides and amino acid
		Dipeptidases	Small Intestine	Dipeptides 'Limit dextrins'	Amino acids
		Isomaltase	Small Intestine	Isomaltose	Glucose
		Maltase	Small Intestine	Maltose	Glucose
		Sucrase/Invertase	Small Intestine	Sucrose	Glucose, fructose
		Lactase	Small Intestine	Lactose	Glucose, galactose
		Lipase	Small Intestine	Triglycerides	Monoglycerides, fatty acids
		Nucleotidase	Small Intestine	Nucleotides	Nucleosides, inorganic phosphate
		Nucleosidase Phosphorylases	Small Intestine	Nucleosides Phosphate	Purine, pyrimidine, pentose, phosphate

9) **Hormonal control of digestion** : Activities of digestive tract are coordinated by nervous and endocrine systems. Sight and smell of food stimulates nervous system which induces the salivary glands to produce large quantity of saliva, stomach to release its

hormone gastrin and intestine to produce intestinal hormones. Other hormones are produced in sequential order. All of them are polypeptide hormones.

**Table : 5.1-5 Gastrointestinal hormones in mammals**

Hormone	Source	Stimulus for secretion	Target organ	Action
Gastrin	Mucosa of pyloric stomach	Distension of stomach on food entry	Stomach	Stimulates secretion of gastric juice Constricts cardiac sphincter
Enterogastrone	Duodenal epithelium	Chyme entry into duodenum	Stomach	Slows gastric contractions to delay its emptying Stops secretion of gastric juice
Secretin	Duodenal epithelium	Acidic chyme entry into duodenum	Pancreas Liver Stomach	Release of sodium bicarbonate in pancreatic juice. Steps up secretion of bile. Inhibits secretion of gastrin
Cholecystokinin (Pancreozymin)	Duodenal epithelium	Presence of fats in duodenum	Pancreas Gall Bladder	Release of enzymes in pancreatic juice Release of bile from gall bladder
Villikin	Intestinal epithelium	Food in small intestine	Intestine	Accelerates movements of villi
Duocnin	Intestinal epithelium (Duodenal mucosa)	Acidic chyme in intestine	Intestine (Brunner's gland)	Release of viscous mucous from Brunner's glands.
Enterocinin	Intestinal epithelium (Duodenal mucosa)	Acidic chyme in intestine	Intestine (crypts of Lieberkuhn's)	Release of enzymes from Lieberkuhn's crypts

## Nutrition

The substance used for nutrition are called nutrients. Nutreology is the study of food and their use in diet and therapy.

### Types of nutrition

(1) **Autotrophic / Holophytic** : The individuals, which synthesizes their own food. It can be grouped into two following categories –

(i) **Photoautotrophs** : The individual, which synthesizes their own food from  $CO_2$  and  $H_2O$  in presence of sunlight. Examples – Green plants, euglena, green sulphur bacteria, chlorobium.

(ii) **Chemoautotrophs** : The individuals which synthesizes their food with the help of chemical. Examples – Sulphur bacteria, nitrite bacteria, nitrate bacteria, nitrosomonas, nitrifying bacteria–nitrosomonas, nitrobacter etc.

(2) **Heterotrophic** : The animals derive organic food materials by consuming bodies or products of other living or dead plants or animals. Heterotrophs are of following three types on the basis of their mode of feeding.

(i) **Holotrophic or Holozoic** : These individuals ingest mostly solid food. Example – Animals.

(ii) **Saprotrophic or Saprobiotic** : They feed on dead organic matter. They absorb food through their body surface, organic fluids formed due to putrefaction of dead organism. Example – Bacteria, fungi, some protozoans etc.

(iii) **Parasitic** : These individuals derive their food from the body of their host. These may live inside or upon the bodies of their hosts, or may only periodically visit them for feeding. e.g., Ectoparasites (Lice) and endoparasites (Ascaris, Taenia solium).

(3) **Myxotrophic nutrition** : They carry out autotrophic as well as heterotrophic nutrition. Example – *Euglena*.

### Modes of animal nutrition

On the basis of food, holozoic or holotrophic or ingestive nutritionally animals are classified into following –

(1) **Herbivorous** : The animal which exclusively feeds on plants. Their length of alimentary canal is more as compared to others. Examples – Tadpole larva of frog, rabbit, cow, horse, sheep etc.

(2) **Carnivorous** : The animal which kills and feeds on other animals. The length of their alimentary canal is minimum. Examples – Tiger, lion etc.

(3) **Omnivorous** : The animal which can take both plant and animal product as food. They have maximum type of digestive enzymes. Example – Human, Dog, Prawn.

(4) **Insectivorous** : The animal which feeds on insects. Example – Frog, Common bats, wall lizards.

(5) **Sanguivorous** : The animal which feeds on blood of other animal. Examples – Leech, body louse, mosquito, vampire bat etc.

(6) **Carrion Eaters (Scavengers)** : They feeds on dead animals also termed as scavengers. Examples – Hyaena, neltura, kites etc.

(7) **Cannibalus** : Organisms which feeds on its own species. Examples – Cockroaches, some fishes, frog, snakes etc.

(8) **Detritus** : Animals feed chiefly upon organic matters present in the humus. Examples – Earthworm.

(9) **Coprophagus or pseudoruminantion or refection** : Animals which feeds on their own faeces. Example – Rabbit, Guinea pig

(10) **Larvivorous** : Feeds on larva. Example – Gambusia (mosquito fish) and Dragon fly.

(11) **Frugivorous** : Feeding on fruits. Example – Parrot, Bat, Squirrel.

(12) **Food robbers** : Feed upon food formed in alimentary canal. Example – Ascaris, Taenia solium.

(13) **Filter feeder** : *Paramecium*, *Unio*, *Sponge*.

### Feeding mechanism

(1) **Feeding mechanism in liquid feeders (fluid feeders)** are as follows –

(i) **Diffusion** : Many parasitic organisms (protozoans, tapeworm) absorb the dissolved organic food through general body surface.

(ii) **Pinocytosis (cell drinking)** : Ingestion of liquid food by invagination through surface of body. Pinocytosis channels are formed at body surface to enclose the fluid food from surrounding medium. Lower ends of channels are pinched off as pinocytic vesicle or pinosomes.

(iii) **Blood sucking** : Their mouthparts are modified for sucking blood. Examples – Vampire bat, mosquito etc.

(2) **Feeding mechanism in microphagus animals (filter feeders)** : The food of such animals (*paramecium*, sponges, corals, bivalves, tadpole etc.) is suspended in water fluid and they have filtering devices (clusters of pseudopodia, cilia, flagella, sheets of mucous etc) or feeding on small microscopic animals like – *Amoeba*, *Paramecium* etc.

### Nutritional requirements

(1) **Food** : All living organism needs food. Animals are unable to synthesize their own food hence they obtain it from outside sources. Animals require food for three main purposes, such as food as a fuel which provides energy and material for body maintenance, food for movement of body includes muscles contraction etc., food for growth as well as for the synthesis of body substances.

(2) **Components of food** : These are of following types –

(i) **Carbohydrates** : They are made up of C : H : O, having H and O in the ratio of 2 : 1 and the general formula is  $(CH_2O)_n$ . They are the chief source of energy. The source of carbohydrates in our food is cereals and pulses.

Table : 5.1-6 Types and examples of carbohydrates

Types of carbohydrate	Examples
Monosaccharides	Glucose (the main blood sugar) Fructose (found in fruits) Galactose (in milk sugar) Deoxyribose (in DNA) Ribose (in RNA)
Disaccharides	Sucrose (table sugar) = glucose + fructose Lactose (milk sugar) = glucose + galactose Maltose = glucose + glucose
Polysaccharides	Glycogen, the stored form of carbohydrate in animals Starch, the stored form of carbohydrate in food Cellulose, part of cell walls in plants; not digested by humans but aids movement of food through intestines



### Specific features

- (1) Storage amount : 900 gm approx.
- (2) Storage site : Chiefly liver and muscles.
- (3) Daily requirement : 500 gm approx.
- (4) Source : Chiefly cereals (rice, wheat, maize), pulses, potato, fruits, sugarcane, milk, honey, sugar etc.
- (5) Caloric value : 4.1 k cal./gm
- (6) Physiological value : 4.0 k cal./gm

### Functions of carbohydrates

- (1) Carbohydrates, especially glucose, are the main respiratory fuels.
- (2) Ribose and deoxyribose sugars are components of nucleic acids (DNA and RNA). Galactose is a structural component of medullary sheath.
- (3) Monosugars act as monomers for the formation of disaccharides and polysaccharides.
- (4) Starch and glycogen, serve as reserve fuel.
- (5) Excess of glucose may also be changed into fats (lipogenesis) and stored in liver, adipose tissue and mesenteries.
- (6) Glucose has antiketogenic role as it prevents the incomplete oxidation of fats and formation of ketonic bodies in the blood.
- (7) Glucose spares the amino acids for protein synthesis.
- (8) Sucrose is the major form in which sugar is transported in the plant body. Sucrose is storage sugar of sugarcane and sugar beet.
- (9) Cellulose, hemicellulose etc. are the main components of cell wall of plants.
- (10) Chitin is main component of cell wall of fungi and exoskeleton of crustaceans.
- (11) Heparin prevents the blood clotting inside the blood vessels (Anticoagulants).
- (12) Glycoproteins form a protective layer, glycocalyx, on intestinal cells.
- (13) Hyaluronic acid acts as a lubricating fluid in the synovial joints between the limb bones
- (14) Blood antigens like A, B and Rh-factor are glycoproteinaceous and provide immunity to the individual.
- (15) Sugars are also important components of some glycoproteinaceous hormones like FSH (Follicular stimulating hormone), LH (Luteinizing hormone) etc. FSH controls gametogenesis while LH controls the ovulation and formation of corpus luteum.
- (16) Carbohydrates may be changed into amino acids.
- (17) Oligosaccharides of cell membrane help in cellular recognition.
- (18) Cellulose forms roughage of food which stimulates the secretion of digestive juices. It also helps in peristalsis.
- (19) Cellulose nitrate is used in explosives.
- (20) Carboxy-methyl cellulose is used in cosmetics and medicines.
- (21) Cellulose acetate is used in preparing cellulose plastics, shatter-proof glass, fabrics etc.

(ii) **Lipids and fats** : Fats and all fat like substances are called lipids. They are composed of C, H and O. They are insoluble in water but soluble in ether, alcohol, chloroform etc.

Table : 5.1-7 Types of lipids in the body

Types of Lipid	Functions
Triglycerides (fats and oils)	Protection, insulation, energy storage
Phospholipids	Major lipid component of cell membranes
<b>Steroids</b>	
Cholesterol	Minor component of all animal cell membranes; precursor of bile salts, vitamin D, and steroid hormones.
Bile salts	Needed for absorption of dietary lipids
Vitamin D	Helps regulate calcium level in the body; needed for bone growth and repair.
Adrenocortical hormones	Help regulate metabolism, resistance to stress, and salt and water balance.
Sex hormones	Stimulate reproductive functions and sexual characteristics.
Eicosanoids	Have diverse effects on blood clotting, inflammation, immunity, stomach acid secretion, airway diameter, lipid breakdown, and smooth muscle contraction.
<b>Other Lipids</b>	
Fatty acids	Catabolized to generate adenosine triphosphate (ATP) or used to synthesize triglycerides and phospholipids.
Carotenes	Needed for synthesis of vitamin A, which is used to make visual pigments in the eyes.
Vitamin E	Promotes wound healing, prevents tissue scarring, contributes to the normal structure and function of the nervous system, and functions as an antioxidant.
Vitamin K	Required for synthesis of blood-clotting proteins.
Lipoproteins	Transport lipids in the blood, carry triglycerides and cholesterol to tissues, and remove excess cholesterol from the blood

### Specific features

- (1) Source : Butter, ghee, liver oil, vegetable cooking oil etc.
- (2) Daily requirement : 50 gm.
- (3) Storage site : Subcutaneous fat, adipose cells.
- (4) Caloric value : 9.45 k cal./gm.
- (5) Actual value : 9.0 k cal./gm.

### Functions of lipids

- (1) The fats acts as concentrated fuel. The caloric fuel value of 1 gm of fats is 9.45 kcal, while the physiological fuel value of 1 gm of fats is 9.0 kcal (37 kJ), which is about 2.25 times more than the energy provided by same amount of glucose.
- (2) The fats are also highly suitable for storage as the reserve food material. It is mainly stored in the liver, beneath the skin, in the brown deposits and in the fat bodies. Normally, the fats constitute about 4% of liver by weight.
- (3) Fats stored in the subcutaneous tissue insulate the body against the loss of heat energy, so conserve the body heat. Thus, fats help in homeothermy.

(4) Medullary sheath is formed of white fatty substance, myelin, which insulates the nerve fibres and prevents the loss of energy.

(5) Fats forms the protective shock absorbing cushions around a number of organs like the eye balls, kidneys (renal fat), ovaries, etc.

(6) These help in the absorption of fat-soluble vitamins like A, D, E and K.

(iii) **Proteins** : They are composed of C, H, O, N and some in addition contain S and P. They are complex, versatile, macromolecules with very high molecular weight. Their unit is amino acids. Out of the 20 amino acids, required in human to build proteins, half of them are essential and rest are non-essential amino acid. Essential amino acids are those, not synthesized by human body and are present in food. The non-essential amino acids are those which can be synthesized by human body.

Table : 5.1-8 Types of amino acids

Dispensable or Essential amino acids	Non-dispensable or Nonessential amino acids
Arginine	Glycine
Histidine	Alanine
Isoleucine	Serine
Leucine	Aspartic acid
Methionine	Asparagine
Phenylalanine	Cystine
Threonine	Glutamic acid
Tryptophan	Glutamine
Lysine	Proline
Valine	Tyrosine

Arginine and histidine are considered semi indispensable amino acids. These two are not essential in the adult organisms.

**Classification of proteins** : They are following types –

(1) **On the basis of structure of molecules**

(i) **Fibrous** : Examples – Collagen, myosin, keratin, fibrin of coagulated blood etc.

(ii) **Globular** : Examples – Albumin, globulin, haemoglobin, enzymes, snake venom etc.

(2) **On the basis of their chemical nature** : The proteins are divided into three categories –

(i) **Simple proteins** : These are formed of peptide chains and yield only amino acids on hydrolysis. On the basis of shape, these may be fibrous proteins e.g. collagen of white fibres, elastin of yellow fibres, keratin of exoskeletal structures like nails, horns, hoofs, hair, feather etc.; globular proteins e.g. albumins and globulin of blood plasma, protamines, histones, glutelins etc.

(ii) **Conjugated proteins** : These are formed of a proteinaceous and a non-proteinaceous prosthetic group. These include nucleoproteins (of chromosomes-DNA and proteins; and ribosomes-RNA and proteins), glycoproteins (of blood-antigens), phosphoproteins (casein of milk), lipoproteins (lipovitellin of egg-yolk), chromoproteins (haemoglobin of RBCs), haemocyanin, rhodopsin (visual purple), iodopsin (visual violet), cytochromes, metalloproteins (carbonic anhydrase enzyme with  $Zn^{2+}$ ) etc.

(iii) **Derived proteins** : These are formed by the partial hydrolysis of simple proteins and include peptones, proteoses etc.

#### Specific features

(1) **Source** : Chief source is pulses, egg, milk, meat, fish, leafy vegetables, soyabean, groundnut etc.

(2) **Daily requirement** : 70-100 gm.

(3) **Caloric value** : 5.6 k cal/gm

(4) **Physiological caloric value** : 4 k cal/gm.

Table : 5.1-9 Types and functions of protein

Types of Protein	Functions
Structural	Form structural framework or various parts of the body <i>Examples</i> Collagen in bone and other connective tissues, and keratin in skin, hair, and fingernails
Regulatory	Functions as hormones that regulate various physiological processes, control growth and development; as neurotransmitters, mediate responses of the nervous system <i>Examples</i> The hormone insulin, which regulates blood glucose level, and a neurotransmitter known as substance P, which mediates sensation of pain in the nervous system
Contractile	Allow shortening of muscle cells, which produces movement. <i>Examples</i> Myosin and actin
Immunological	Aid responses that protect body against foreign substances and invading pathogens. <i>Examples</i> Haemoglobin which transports most oxygen and some carbon dioxide in the blood
Catalytic	Act as enzymes that regulate biochemical reactions <i>Examples</i> Salivary amylase, sucrase and ATPase.

(iv) **Vitamins**

#### Historical review

N. I. Lunin (1881) discovered vitamins. The term 'vitamin' was first used by Funk in 1912. Hopkins and Funk (1912) propounded a 'vitamin theory'.

**Definition** : Vitamin are complex organic compounds needed daily in minute quantities and act as growth and metabolic regulatory substances.

**Sources** : Vitamins can only be synthesized by green plants, hence animals depend for their vitamin requirement upon the plants. Human body manufactures vitamin D using ultraviolet rays of sunlight and can store A, D, E, K and B<sub>12</sub>. The chemical compositions of vitamins are known and it is possible to synthesize them.

**Importance** : The vitamins are not a sources of energy. They regulate the various metabolic processes. They mostly act as the constituents of coenzymes in the cells

**Types** : Vitamins are divided into two groups –

(a) **Fat soluble vitamin** : A, D, E and K.

(b) **Water soluble vitamin** : B complex and C.

Table : 5.1-10 Fat soluble vitamins

Name of vitamins and chemical formula	Discovery	Sources	Daily requirement per day	Functions	Name of Deficiency Disease	Symptoms	Other Features
Vitamin A or Retinol or anti xero-phthalmic or anti infection vitamin $C_{20}H_{29}O$	Mc-Collum and Davis (1913)	Butter, liver oils, egg yolk, mango and orange, carrot, yellow, green vegetables	2 mg	Part of visual pigment, maintenance of epithelia and prevention of keratinization of epithelium. Beta carotene act as Antioxidants.	Xerophthalmia Night blindness or nyctalopia Keratomalacia Dermatosis	Drying of eyeball Unable to see in dim light Epithelium keratinised Dry scaly skin	Synthesized and stored in the liver Destroyed by - strong light
Vitamin D or Ergocalciferol or sunshine vitamin or anti ricket vitamin $C_{28}H_{44}O$	Steenbock and Hess (1924)	Cod liver oil, butter, fish, eggs, milk, brain, lung, and spleen	0.01 mg	Facilitates absorption of calcium and phosphorus by intestine and their retention in body and deposition in bones.	Rickets in children Osteomalacia in adults	Deformities of bones like bowlegs, pigeon chest Weak bones liable to easy fracture	Synthesized in the body on exposure of skin (7 hydroxy cholesterol) to light. Destroyed by - oral contraceptives
Vitamin E or $\alpha$ -Tocopherol or anti sterility vitamin $C_{29}H_{46}O_2$	Evan and sore (1922)	Fresh green vegetables, meat, yolk, vegetable oils, butter and cheese, peanuts wheat germs.	20 mg	Antioxidant and some role in ETS. DNA / RNA/RBC formation promote wound healing	Anaemia Sterility Muscular atrophy	Destruction of RBC In male causes sterility and in female abortion may occur Effort not proved in man Degeneration of muscles	Destroyed by UV - rays It is also used for curing tumour and cancer
Vitamin K or Phylloquinone or anti haemorrhagic vitamin $C_{31}H_{46}O_2$	Dam and Droisy (1935)	Fresh green vegetables tomatoes, liver, soyabean, cheese, egg.	0.07 - 0.14 mg	Synthesis of prothrombin for normal clotting of blood.	Haemorrhage	Reduced ability of blood to clot and also leads to haemorrhages.	Vitamin K is synthesised by intestinal microbes present in the intestine Destroyed by - prolonged use of antibiotics.

Table : 5.1-11 Water soluble vitamins

Name of Vitamins and Chemical Formula	Discovery	Sources	D.R.	Function	Name of Deficiency Disease	Symptoms	Other Features
Vitamin $B_1$ or Thiamine or anti neuritic or antiberberi $C_{12}H_{16}N_4SO$	C Funk (1926)	Brannice, whole wheat flour, egg, meat, liver yeast etc	1-1.5 mg	Act as an enzyme in cellular respiration, role in nutrition of nerve cells. Essential for carbohydrate metabolism, protein synthesis and control water balance in body. Major component of co-enzyme carboxylase.	Beri- beri or Dry beri - beri (man) Polymeunitis or wet beri - beri (animals) Cardiovascular atrophy	Loss of appetite and weight, retarded growth, muscular dystrophy. Nerves become extremely irritable. Heart enlargement	Beri-beri disease was discovered by Eijkman Destroyed by - cooking

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Vitamin B <sub>2</sub> or G or yellow enzyme or Riboflavin or Lactoflavin or ovaflavin or hepatoflavin $C_{17}H_{26}N_4O_6$	Warburg and Christain	Cheese, egg, yeast, meat, liver, cereals, green vegetable	1-2 mg	Required for cell growth  Form pair of coenzyme (FMN, FAD).	Cheilosis  Glossitis  Keratitis	Cracking of skin at corners of mouth  Inflammation of tongue  Inflammation of skin	Stored in liver, Excess of this is eliminated in urine  It is associated with the physiology of vision
Vitamin B <sub>3</sub>  Yeast factor or pantothenic acid or anti greying factor on chick antidermatitis factor $C_9H_{17}O_5N$	Williams (1933)	All foods, more in yeast, kidney, liver, egg, meat, milk, ground nut	5-10 mg	Part of co-enzyme A needed for cell respiration, necessary for normal skin and nerves.	Burning feet syndrome.  Nervous disorder	Nerve degeneration	It occurs in all types of plants and animal tissues.  Its deficiency cause greying of hair
Vitamin B <sub>5</sub> or Niacin or Nicotinic acid or pellagra preventing factor $C_6H_5NO_2$	Goldberger (1912)	Fresh meat, liver, fish, milk, cereals, pulses, yeast etc.	16-20 mg	It is an essential component of NAD and NADP thus form coenzymes, metabolism of carbohydrates, functioning of gastrointestinal tract and nervous system	Pellagra, Dermatitis.  Diarrhoea  Dementia  Death (4-D syndrome)	Rough skin  Inflammation of skin which becomes scaly and papillated  Dehydration  Neural deterioration which may lead to madness	It is characterised by 3D's i.e. dermatitis, diarrhoea and dementia  Destroyed by - cooking  Pellagra preventing factor Goldberger also called Goldberger's p-p factor  It is also synthesized by colon bacteria
Vitamin B <sub>6</sub> or pyrido-xine or anti dermatitis factor $C_8H_{11}O_3N$	Gyorgyi (1928)	Brewer's yeast, liver, egg, yolk, kidney, milk, and vegetables	2 mg	It is essential component of coenzyme pyridoxal phosphate. It promotes growth in rats used for curing tuberculosis.	Anaemia  Dermatitis, paralysis & death of rats  Mental disorder  Dermatitis	Nausea, lack of RBC (blood)  Disturbance of central nervous system  Skin lesions	Term B <sub>6</sub> was coined by Gyorgy  Destroyed by - cooking and oral contraceptives
Vitamin H or B <sub>7</sub> or Biotin or coenzyme R $C_{10}H_{16}N_2O_3S$	Bateman and Allison (1916)	Yeast, vegetables and egg yolk	150-300 mg	It acts as coenzymes and essential for fat synthesis and energy production.	Dermatitis	Scaly and itchy skin	It is synthesized by intestinal bacteria Destroyed by - prolonged use of antibiotics
Folic Acid or Vitamin M or folacin or Anti anaemic factor	Day (1935)	Green vegetable (spinach) Banana, orange and Liver.	0.4 mg	It forms coenzymes and play essential role in cell metabolism, Necessary for erythropoiesis, required for DNA synthesis	Megaloblastic anaemia  Sprue	Enlarged RBCs  Ulceration of mouth	It is also synthesized by intestinal bacteria  Destroyed by - cooking

Vitamin B <sub>12</sub> or Cyanocobalamin or Animal protein factor (APF) or Intrinsic factor of cattle $C_{55}H_{88}O_{14}N_{14}PCo$	Rickets (1948)	Meat, egg, liver, fish, synthesized by intestinal bacteria.	0.003 mg	Required for chromosome duplication and formation of blood corpuscles.	Pernicious anaemia	Reduced formation of erythrocytes in bone marrow	It is also known as anti pernicious factor Also synthesized by intestinal bacteria in human colon Destroyed by – excessive heat
Vitamin C or Ascorbic Acid $C_6H_8O_6$	Szent Gyorgyi (1928)	Citrus fruits such as lemon, mango, amla, plumes, guava.	40-60 mg	Functions as part of oxidation- reduction system. Helps in secretion of collagen cement dentine. Helps body to develop resistance to diseases. Helps in absorption of Ca and Fe in the intestine Wound healing.	Scurvy	Spongy and bleeding gums, fragile blood vessels and bones.	Required by primates, all other vertebrates and some other invertebrates can synthesize vitamin C. It is the earliest known vitamin it is wound healing vitamin. Destroyed by heating

Table : 5.1-12 Other Types of vitamins, functions and deficiency symptoms

Name of Vitamin	Function	Symptoms of deficiency
Inositol or mouse antialopecia factor	Stimulate growth of mice Spectacle-eye condition in rat can be treated. Keep a limit on the cholesterol level in the blood of man	Causes reduced growth and alopecia (loss of hair) in the mice. Also causes haemorrhagic degeneration of the adrenal gland.
Choline	It is an important lipotropic factor which prevent excessive development of fatty liver. It takes part in the formation of acetylcholine which is involved conduction of nerve impulse	Chronic deficiency causes cirrhosis in the liver also causes haemorrhagic changes in kidney.
Vit P or citrin	Control the permeability and fragility of the capillary wall to plasma protein works as the co-factor with vitamin C.	Its deficiency causes subcutaneous bleeding due to break down of capillary walls

(vii) **Mineral elements** : They forms approximately 4% of body weight. They are essential to regulate the various metabolic activities of the animals. The various types of mineral are group into two categories as minor element. Examples – Ca, S, P, Na etc. and trace element examples – Cu, Zn, Mn etc. Some of these minerals are described as follows –

Table : 5.1-13 Chart of important minerals required in animal bodies

Mineral elements	Sources	Significance	Effects of deficiency
<b>Minor elements</b>			
(1) Calcium–Ca	Milk, Cereals, Cheese Green Vegetables, Pods.	Required for formation of teeth and bones, blood clotting, functions of nerves and muscles	Weak teeth and bones, retarded body growth.
(2) Phosphorus–P	Milk, Meat, Cereals.	Required for formation of teeth and bones and acid-base balance; component of ATP, DNA, RNA.	Weak teeth and bones, retarded body growth and physiology.
(3) Sulphur–S	Many proteins of food	Component of many amino acids	Disturbed protein metabolism
(4) Potassium–K	Meat, Milk, Cereals, Fruits and Vegetables	Required for acid base balance, water regulation and function of nerves	Low blood pressure, weak muscles, risk of paralysis
(5) Chlorine–Cl	Table Salt.	Required for acid-base balance; component of gastric juice	Loss of appetite, muscle cramps
(6) Sodium–Na	Table Salt	Required for acid-base and water balances and nervous functions.	Low blood pressure, loss of appetite, muscle cramps
(7) Magnesium–Mg	Cereals, Green Vegetables.	Cofactor of many enzymes of glycolysis and a number of other metabolic reactions dependent upon ATP	Irregularities of metabolism, principally affecting nervous functions.

(8) Iron-Fe	Meat, Eggs, Pods, Cereals, Green Vegetables.	Component of haemoglobin and cytochromes.	Anaemia, weakness and weak immunity
(9) Iodine-I	Milk, Cheese, Seafood, Iodized salt	Important component of thyroxin hormone and regulate metabolism of cell	Goitre, cretinism.
<b>Trace Elements</b>			
(10) Fluorine-F	Drinking water, Tea, Seafood	Maintenance of bones and teeth	Weak teeth. Larger amount causes mottling of teeth.
(11) Zinc-Zn	Cereals, Milk, Eggs, Meat, Seafood	Cofactor of digestive and many other enzymes.	Retarded growth, anaemia, rough skin, weak immunity and fertility.
(12) Copper-Cu	Meat, Dry fruits, Pods, Green Vegetables, Seafood.	Cofactor of cytochrome oxidase enzyme. Necessary for iron metabolism and development of blood vessels and connective tissues	Anaemia, weak blood vessels and connective tissue and damage to central nervous system.
(13) Manganese-Mn	Dry fruits, cereals, Tea, Fruits and Green Vegetables.	Cofactor of some enzymes of urea synthesis and transfer of phosphate group.	Irregular growth of bones, cartilages and connective tissues.
(14) Cobalt-Co	Milk, Cheese, Meat.	Important component of vitamin B <sub>12</sub>	Anaemia.
(15) Selenium-Se	Meat, Cereals, Sea food	Cofactor of many enzymes, assists vitamin E	Muscular pain, weakness of cardiac muscles
(16) Chromium-Cr	Yeast, Seafood, Meat, Some vegetables.	Important for catabolic metabolism	Irregularities of catabolic metabolism and ATP production.
(17) Molybdenum-Mo	Cereals, Pods, Some Vegetable	Cofactor of some enzymes	Irregular excretion of nitrogenous waste products.

### Nutritional imbalances and disorders

**Balanced diet :** The diet which contains the various nutrients in such proportions as can satisfy all the various needs of our body, is called a "balanced diet"

**Table : 5.1-14 Balanced diet for moderately active adult Indian**

Name of food	Recommended amounts (gms. per day)	
	Adult	Adult woman
(1) Cereals (Wheat/Rice)	520	440
(2) Pulses	50	45
(3) Milk	200	150
(4) Meat/Fish or Egg	30	30
(5) Fats (Oil, Butter, Ghee)	45	25
(6) Sugar/Molasses	35	20
(7) Root and Tubers (Raddish, Potato, etc.)	60	50
(8) Green leafy vegetables	40	100
(9) Other vegetables	70	40

**Table : 5.1-15 Daily Dietary Requirements of Nutrients (Recommended by Indian Council of Medical Research)**

Individual	Total kcal	Protein (gms.)	Calcium (gms.)	Iron (mgs.)	Vitamin A (μg.)	Thiamin (mgs)	Riboflavin (mgs.)	Niacin (mgs.)	Folacin (μg.)	Vitamin B <sub>12</sub> (μg.)	Vitamin C (mgs.)	Vitamin D (IU)
(1) Man Moderately active	2800	55	0.4-0.5	24	750	1.4	1.7	19	100	1	40	
(2) Woman	2200	45	0.4-0.5	32	750	1.1	1.3	15	100	1	40	
(i) Moderately active	2700	59	1.0	40	750	1.3	1.5	17	300	1.5	40	
(ii) Pregnant	2750	70	1.0	32	1150	1.4	1.6	19	150	1.5	80	

The proportion of carbohydrates, proteins and fats into fulfill energy requirement is 4 : 1 : 1 i.e. 65% of energy is obtained from carbohydrates and 10-20% each from proteins and fats. This amount of energy is fulfilled by intake of 400-600 gm of carbohydrates, 80-100 gm of proteins and 50-60 gm of fats. The balanced diet must also contain sufficient amount of minerals and vitamins.

#### Metabolic rates

(1) **Basal metabolic rate :** Amount of energy required daily by a person to maintain its basal metabolism and is about 1600 k cal/day.

(2) **Routine metabolic rate :** Amount of energy required daily by a person to do his routine work. It is about 2800 k cal/day for males and 2300 k cal for female.

(3) **Active metabolic rate :** Amount of energy required daily by a person to maintain its high metabolic rate during heavy physical work and is about 4000 to 6000 k cal/day for males and 4500 k cal for females. It has been scientifically determined that a child of 4-6 years approximately requires 1500, a child of 13-15 years requires 2500 and a youth of 16-18 year requires 3000 k cal of energy per day.

(3) Boy (16-18 years)	2820	53	0.5-0.6	25	750	14	17	19	100	1	40	200
(4) Girl (16-18 years)	2200	44	0.5-0.6	35	750	11	13	15	100	1	40	200

**Nutritional disorders :** Every organism requires an adequate supply of nutrients in proper proportion in their diet for proper growth and development. There are two types of nutritional disorders

**(1) Diseases due to over nutrition**

(i) **Fluorosis :** Caused due to excess of fluorides. It results in tooth and bone decay.

(ii) **Obesity :** This is over-nutritional disorder. It is caused when "energy inputs exceeds energy output". It results in deposition of excess fat in the body.

(iii) **Constipation :** Slow movement of faeces down the large intestine causes accumulation of dry and hard stool in colon. It is generally caused by irregular bowel habits.

(iv) **Diarrhoea :** Rapid movement of faecal matter down the large intestine causes loose stools called diarrhoea. It may be also caused by viral or bacterial infections of intestinal tract, particularly of large intestine and by nervous tension.

(v) **Piles or haemorrhoids :** Enlargement of the anal veins. It may be either hereditary or may be caused due to rapid changes in the diet.

(vi) **Hypercholesterolemia :** Caused due to excess of saturated fats like butter, ghee, hydrogenated vegetable oils and eggs etc. It results in increased level of cholesterol in blood, arteriosclerosis, coronary thrombosis, heart attack etc.

(vii) **Hypervitaminosis A :** It results in loss of appetite, body hairs, painful swelling etc.

(viii) **Hypervitaminosis D :** It results in deposition of calcium ion in the soft tissues of the body.

**(2) Diseases due to deficiency of nutrition (malnutrition)**

Name of the Deficiency	Deficient Nutrient	Symptoms
Anaemia (microcytic)	Fe	Haemoglobin and number of erythrocytes gets reduced.
Megaloblastic anaemia	Folic acid and $B_{12}$	Presence of immature erythrocytes in blood
Pernicious anaemia	Vitamin $B_{12}$	Immature RBC without Hb. This may be fatal unless treated with vitamin $B_{12}$ injection
Xerophthalmia	Vitamin A	Thickened, keratinised opaque ulcerated cornea. Prime cause of blindness in India, especially among children
Night Blindness	Vitamin A	Less rhodopsin in rod cells of retina. So no vision in dim light
Rickets (in children)	Vitamin D	Weak, soft, thin bones due to poor deposition of Ca and P. Bent long bones and painful swelling on wrist, elbow and knee joints
Osteomalacia (adults)	Vitamin D	Weak bones of vertebral column, pelvis gets bent and deformed by body weight
Scurvy	Folic acid	Ulceration of mouth, inflammation of bowel, indigestion, diarrhoea, weakness
Pigeons breast	Vit. D	Incomplete ossification at the end of limb bone, deformed ribs leading to pigeons breast
Beri-beri	Vitamin $B_1$ (Thiamine)	Reduces aerobic carbohydrate metabolism. So peripheral nerves are inflamed causing pain, numbness and weakness of limb muscles. Paralysis. Fluid accumulation in tissues or oedema of hands and legs. Cardiac oedema
Scurvy	Vitamin C	Fragile blood vessels because of defective collagen fibres in their walls. Bleeding gums, teeth fall, bones fragile. Wound healing delayed, vitamin C is recommended in serious injury
Bleeding disease (Hypoprothrombin anaemia)	Vitamin K	Delayed blood clotting (s) so profuse bleeding.
Marasmus	Protein Malnutrition	Growth and replacement of tissue proteins impaired so emaciated body with thin limbs and prominent ribs, dry, thin and wrinkled skin, Diarrhoea. It affects infants under one year of age
Kwashiorkor	Protein	Wasting muscles, thin limbs. Retarded growth of body and brain, Oedema, Diarrhoea. It commonly affects babies between 1-3 years of age
Pellagra	Nicotinamide	Swollen lips, thick pigmented skin of hands and legs. Irritability
Osteoporosis	Ca	Weakening of bones, tooth decay
Goitre	$I_2$	Enlargement of thyroid gland
Muscular cramps	NaCl	Pulling of muscles due to dehydration
Dental cramps	Fluorine	Tooth decay

## Regulation of food intake

**Hunger** : Hunger is defined as the intrinsic (involuntary) desire or craving for food. Hunger is associated with a number of objective sensations. For instance, food deprivation for many hours causes intense rhythmic hunger contractions in stomach, which even causes intense pain (hunger pangs) send sensory impulses to a "hunger or feeding centre", located in the lateral regions of hypothalamus.

When glucose levels fall in blood, hunger centre is stimulated. Hunger centre transmits impulses to wall of stomach and wall of empty stomach start contraction or hunger pangs. After taking meal satiety centre which is located in hypothalamus stimulates and feeding is stopped. During high fever person does not feel like taking meal because high temperature shuts off the appetite centre.

**Thirst** : Subconscious desire for water is called thirst. It is also induced by a hypothalamic "thirst centre". When amount of water decreases in body fluids (blood, lymph, tissue fluid, cerebrospinal fluid etc.) due to fever, exercise and sweating, copious urination, diarrhoea, etc. This induces the feeling of thirst. Presumably, a fall in glucose level in the blood also induces thirst.

## Tips & Tricks

✚ Upper canine form tusk in walrus for digging mollusc and for locomotion.

✚ In carnivores, last premolars in upper jaw and first molars in lower jaw may have very sharp cusps for cracking bones and shearing tendons. These are called carnassial teeth.

✚ **Tonsillectomy** – Surgical removal of tonsil.

✚ **Cheek pouches** – In some rodents (squirrel, rat) certain old world monkey, the vestibule extends to form cheek pouches for temporary storage of masticated food.

✚ Elephant tusk is the upper incisors.

✚ Teeth of fishes are modified placoid scales.

✚ Pyorrhoea infected gums and tooth sockets.

✚ Maximum number of teeth present in opossum is  

$$\frac{5134}{4134} \times 2 = 50$$

✚ The number of teeth that grows once and twice in humans life is 12 and 20 respectively.

✚ **Lophodont** : Cusps of premolars and molars fuse and form transverse ridges e.g. in elephant.

✚ **Jacobson organ** (Vomer nasal organs) – This organ serve to smell food and recognize its chemical nature. They also help enemy recognition, locating members to opposite sex, courtship etc. It is found in reptiles such as lizards, snakes and sphendon.

✚ Taste of chilli is not real taste but it is burning sensation of nerves

✚ Fangs of poisonous snake attached to maxillary bones, they are replaceable. Solenoglyphous, Proteroglyphus and Opisthoglyphus types of fang occurs in poisonous snake.

✚ Greenish faecal matter passed by infant in first two days of birth due to sterilized intestine is called meconium

✚ National institute of nutrition is located in Hyderabad.

✚ Gastritis – Inflammation of stomach.

✚ Amount of rennin decreases with age, then the curdling of milk is done by pepsin and chymotrypsin.

✚ Removal of stomach causes dumping syndrome.

✚ Oesophagus does not secrete any enzyme.

✚ Stomach absent in labeo, lamprey and hag fish

✚ The study of alimentary canal is called Gastro-Enterology.

✚ Digestion of cellulose is also found in termites (white ants). In which symbiotic flagellate Triconympha found in their intestine that secretes enzyme  $\beta$ -glucosidase which hydrolyse the cellulose to sugars which are used by both symbionts.

✚ Bursa fabricious is also called cloacal thymus, is a lymphoid mass in the cloaca of birds. It is site of differentiation of B-lymphocytes. So a part of immune system.

✚ Carnivores, cattles and other cud-chewing mammals lack ptyalin enzymes in their saliva.

✚ Pepsin hydrolyses the peptic bonds on c-terminus side of tyrosine, tryptophan and methionine amino acids.

✚ Trypsin is called universal enzyme as found from protozoans to mammals.

✚ Nucleases of pancreatic juice digest about 80% of nucleic acid

✚ Pancreatic juice is called as "complete digestive juice" as it is protease enzymes can break all type of peptide bonds.

✚ Amylases act on glycoside linkages.

✚ Pepsin, trypsin and chymotrypsin are endopeptidases whereas carboxy peptidase is exopeptidase.

✚ Blood is digested by trypsin.

✚ Enterokinase is a non-digestive protease while bile is a non-enzymatic digestive juice.

✚ Galactosemia is a disease of children in which amount of galactose increases in blood. Such children are kept on milk free diet

✚ Sphincter of boyden is absent in rabbit and frog.

✚ **Cholecystectomy** – Surgical removal of gall bladder.

✚ Liver produces biles, cholesterol and iron.

✚ Prussic acid formed during metabolism is rendered harmless by liver.

✚ Septicaemia anaemia causes destruction of liver.

✚ Bile is alkaline in man but acidic in cats and dogs

✚ Choleretic are substance which increase bile secretion from liver e.g. bile salts.



# Ordinary Thinking

## Objective Questions

### Digestive System

- In mammals the lower jaw is made up of [MP PMT 1998; BVP 2001]
 

(a) Dentary	(b) Maxilla
(c) Premaxilla	(d) Palatine
- Dental formula of rabbit is [CPMT 1994, 98, 2010; Bihar CECE 1995]
 

(a) $\frac{1023}{1023}$	(b) $\frac{3023}{3023}$
(c) $\frac{1023}{2023}$	(d) $\frac{2103}{2304}$
(e) $\frac{2033}{1023}$	
- Which one has a developed canine [MP PMT 1995]
 

(a) Polar bear	(b) Walrus
(c) Male elephant	(d) Rhinoceros
- The hardest substance of vertebrate body is [NCERT; MP PMT 1995; RPMT 2006]

Or

- Crown of teeth is covered by [AFMC 2005; MP PMT 2013]
 

(a) Keratin	(b) Enamel
(c) Dentine	(d) Chondrin
- On the tongue of rabbit which type of papillae are present but absent in human
 

(a) Circumvallate	(b) Circumvallate and foliate
(c) Foliate	(d) Fungiform
- The layer lining the lumen of the human alimentary canal is [Kerala PMT 2012]
 

(a) Serosa	(b) Sub-mucosa
(c) Muscularis	(d) Pleura
(e) Mucosa	
- The back flow of faecal matter in the large intestine is prevented by the presence of [NCERT; Kerala PMT 2011]
 

(a) Epiglottis
(b) Sphincter of Oddi
(c) Ileo-Caecal valve
(d) Gastro-oesophageal sphincter
(e) Pyloric sphincter
- In mammals the teeth are
 

(i) Of different types
(ii) Embedded in the cup-like socket of the jaw bones
(iii) Only two sets, present throughout life

 These conditions are referred as

[Kerala PMT 2007, 09; Odisha JEE 2009]

Or

Teeth of rabbits are [CPMT 2004]

- |  |
|--|
| (a) Heterodont, thecodont and diphyodont |
| (b) Thecodont, heterodont and diphyodont |
| (c) Diphyodont, thecodont and heterodont |
| (d) Heterodont, diphyodont and thecodont |
| (e) Thecodont, diphyodont and heterodont |

- It is a correct dental formula for the child falling under age group 5-6 yrs. [GUJCET 2007, 09]

- |                                |                                |
|--------------------------------|--------------------------------|
| (a) $I2/2, C1/1, P M2/2, M0/0$ | (b) $I2/2, C1/1, P M2/2, M3/3$ |
| (c) $I1/1, C2/2, P M2/2, M3/3$ | (d) $I2/2, C2/2, P M1/1, M3/3$ |

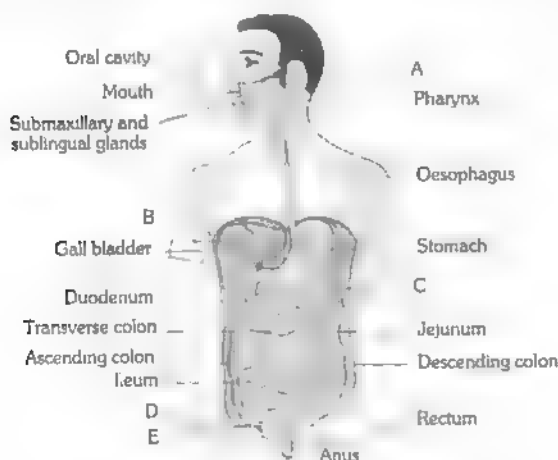
- ✎ Cholagogues are substances which causes the contraction of the gall bladder.
- ✎ Obstructive jaundice is the condition when hepatic or common bile duct may be obstructed and failing to be excreted bile by the bile capillaries.
- ✎ World food day (W.F.D) is 16<sup>th</sup> october.
- ✎ **White revolution** – Increased milk production.
- ✎ **Blue revolution** – Increased fish production.
- ✎ **Yellow revolution** – Increased oil production.
- ✎ The foul & flatus odour of the faeces is due to presence of gases such as  $CH_4$ ,  $NH_3$ ,  $H_2S$ ,  $CO_2$  etc. and presence of indole, skatole and mercaptanes amines formed due to decarboxylation of tryptophan amino acid.
- ✎ Villus is the unit of absorption of food.
- ✎ The enzymes that converts glucose to glucose 6-phosphate is hexokinase.
- ✎ Human insulin is known as Humulin.
- ✎ Fructose is the sweetest sugar found in fruits but not in grapes.
- ✎ Glycogen is also called as “animal starch”
- ✎ Zinc is necessary to maintain plasma concentration of vitamin A.
- ✎ Vertebrates cannot digest keratin protein of hair, nails, fibroin protein of silk fibers etc, but certain insects can digest these proteins so damages silken and woolen garments.
- ✎ Vitamin C was the first vitamin to be produced during fermentation process using wild bacteria
- ✎ An alcoholic is always deficient of vitamin C.
- ✎ Vitamin  $B_{17}$  is a recently discovered vitamin with anti-cancer property.
- ✎ Most of the B-complex vitamins are coenzymes.
- ✎ Presently vitamin  $B_{12}$  is produced directly during the course of fermentation by propionl bacteria and certain strains of *Pseudomonas*.
- ✎ Vitamins, which are synthesized by the intestinal flora are vitamin K. Thiamine, Riboflavin, Pantothenic acid, Niacin, Pyridoxin, Biotin and Folic acid.
- ✎ Gama – linolenic acid and arachidonic acids are essential fatty acid in mammals.
- ✎ Phenyl alanine amino acid is denoted by symbol F.
- ✎ The overdosage of vitamin ‘A’ causes injury to lysosomes.
- ✎ Vitamin  $B_6$  is essential for transmission.
- ✎ Frog tadpole is delayed in metamorphosis due to less amount of iodine in water.
- ✎ The most complex amino acid having double rings structure is tryptophan.
- ✎ The intestinal bacteria are able to synthesize both essential amino acids and vitamins in ruminants.
- ✎ Whiptail disease is caused due to the deficiency of molybdenum

10. The mucosal layer in the stomach form irregular folds known as [NCERT; Kerala PMT 2011]  
(a) Villi (b) Lumen  
(c) Rugae (d) Crypts of Lieberkuhn  
(e) Lacteals
11. A pair of small lymphatic tissue present at the sides of root tongue is called as [CBSE PMT 1993]  
(a) Thyroid (b) Tonsils  
(c) Epiglottis (d) Adenoids
12. Vomerine teeth are present in  
(a) Man (b) Reptiles  
(c) Frogs (d) Rabbits
13. The function of tongue is to [CBSE PMT 1993]  
(a) Help in the act of swallowing  
(b) Help in mixing saliva with the food  
(c) Help in speaking  
(d) All the above
14. The primary dentition in human differs from permanent dentition is not having one of the following type of teeth [AIPTM 2015]

Or

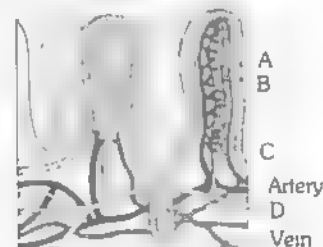
A baby boy aged two years is admitted to play school and passes through a dental check-up. The dentist observed that boy had twenty teeth. Which teeth were absent [NEET 2017]

- (a) Premolars (b) Molars  
(c) Incisors (d) Canine
15. Taste buds for bitter taste are found on tongue at  
(a) Tip (b) On basal surface  
(c) Posterior part (d) Lateral sides
16. The given figure shows the human digestive system. Identify A, B, C, D and E respectively [NCERT]

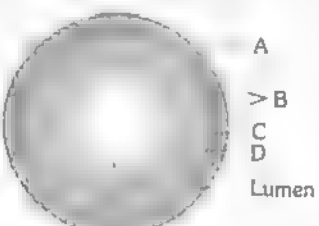
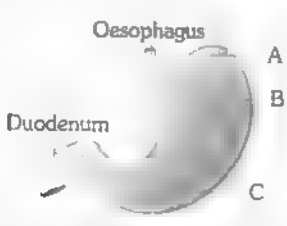


- (a) A - Parotid gland, B - Liver, C - Caecum, D - Pancreas, E - Vermiform appendix  
(b) A - Parotid gland, B - Caecum, C - Pancreas, D - Liver, E - Vermiform appendix  
(c) A - Parotid gland, B - Pancreas, C - Liver, D - Caecum, E - Vermiform appendix  
(d) A - Parotid gland, B - Liver, C - Pancreas, D - Caecum, E - Vermiform appendix

17. Two friends are eating together on a dining table. One of them suddenly starts coughing while swallowing some food. This coughing would have been due to improper movement of [NCERT; CBSE PMT (Pre.) 2011]  
(a) Tongue (b) Epiglottis  
(c) Diaphragm (d) Neck
18. If for some reason our goblet cells are non-functional, this will adversely affect [CBSE PMT (Pre.) 2010]  
(a) Smooth movement of food down the intestine  
(b) Production of somatostatin  
(c) Secretion of sebum from the sebaceous glands  
(d) Maturation of sperms
19. In mammals, the digestion of starch starts from [NCERT; CPMT 1995; BHU 2001; MHCET 2003; BCECE 2006]  
(a) Mouth (b) Stomach  
(c) Oesophagus (d) Duodenum
20. If the dental formula of Rabbit is 2033/1023. What does it show [CPMT 1993; Manipal 1995; RPMT 2001]  
(a) Total number of teeth in Rabbit is 15  
(b) Number of total incisors in Rabbit is 3  
(c) Diastema is present between incisors & premolars  
(d) In the formula 2033 is for adult and 1023 is for young ones
21. Which of the following teeth are lophodont [CPMT 1998; AIIMS 2002]  
(a) Incisor and canine (b) Premolar and molar  
(c) Canine and premolar (d) Premolar and incisor
22. The given figure shows a section of small intestinal mucosa showing villi. Identify A to D [NCERT]



- (a) A - Crypts, B - Lacteal, C - Capillaries, D - Villi  
(b) A - Villi, B - Lacteal, C - Crypts, D - Capillaries  
(c) A - Lacteal, B - Villi, C - Capillaries, D - Crypts  
(d) A - Villi, B - Lacteal, C - Capillaries, D - Crypts
23. Tusk of an elephant is an enormously enlarged [AFMC 2000; HP PMT 2005; Odisha JEE 2010]  
(a) Upper canine (b) Lower incisor  
(c) Upper incisor (d) Lower canine
24. The type of muscle fibre present in the wall of alimentary canal is [Odisha JEE 2010]  
(a) Smooth muscle fibre (b) Striped muscle fibre  
(c) Cardiac muscle fibre (d) Both (a) and (b)
25. Which of the following is vestigial teeth found in human [Pb. PMT 2000]  
(a) Incisors (b) Premolars  
(c) Diphyodont (d) Wisdom tooth

26. Teeth in frog are [BHU 2002]  
 (a) Acrodont (b) Homodont  
 (c) Polyphyodont (d) All of these
27. Pulp cavity of teeth is lined by [RPMT 2000, 06; CPMT 2002]  
 (a) Odontoblast (b) Chondroblast  
 (c) Osteoblast (d) Amyloblast
28. Lacteals are central lymph vessels which are found in [NCERT; CPMT 1996]  
 (a) Liver (b) Pancreas  
 (c) Villi (d) Spleen
29. In the wall of alimentary canal which are/ is true sequence from outer to inner [NCERT; BHU 2003]  
 (a) Serosa, longitudinal muscle, mucosa, sub mucosa  
 (b) Mucosa, serosa, long muscle  
 (c) Serosa, long muscle, circular, sub-mucosa, mucosa  
 (d) Serosa, long muscle, sub-mucosa, mucosa
30. Dental formula of human being is [NCERT; Manipal 1995; MP PMT 2001, 03, 11; Odisha JEE 2004; BCECE 2005; DPMT 2006]  
 (a)  $I_2, C_2, P_1, M_3$  (b)  $I_2, C_1, P_2, M_3$   
 (c)  $I_3, C_1, P_2, M_2$  (d)  $I_2, C_2, P_3, M_1$
31. Some of the animals eat their faeces to digest the cellulose contents again, such animals are known as [DPMT 2003; Odisha JEE 2004]  
 (a) Sanguivorous (b) Frugivorous  
 (c) Coprophagous (d) Deteritivorous
32. The given diagram indicates the TS of Gut. Identify A, B, C and D [NCERT]
- 
- (a) A - Serosa; B - Submucosa; C - Muscularis; D - Mucosa  
 (b) A - Serosa; B - Muscularis; C - Mucosa; D - Submucosa  
 (c) A - Muscularis; B - Serosa; C - Submucosa; D - Mucosa  
 (d) A - Serosa; B - Muscularis; C - Submucosa; D - Mucosa
33. The given diagram represent anatomical regions of human stomach. Identify A, B and C [NCERT]
- 
- (a) A - Pyloric; B - Fundus; C - Cardiac  
 (b) A - Fundus; B - Cardiac; C - Pyloric  
 (c) A - Cardiac; B - Fundus; C - Pyloric  
 (d) A - Fundus; B - Pyloric; C - Cardiac
34. The muscular contraction in the alimentary canal is known as [NCERT; MP PMT 1994; RPMT 1999]  
 (a) Systole (b) Diastole  
 (c) Peristalsis (d) Metachronal
35. Fundic part of stomach is  
 (a) Present in rabbit but absent in frog  
 (b) Absent in rabbit but present in frog  
 (c) Absent in both rabbit and frog  
 (d) Present in both rabbit and frog
36. HCl is secreted by [NCERT; MP PMT 1999, 2009; AFMC 2005; DPMT 2006; WB JEE 2010; Odisha JEE 2011; PET (Pharmacy) 2013]  
 (a) Zymogen cells (b) Oxyntic cells  
 (c) Kupffer cells (d) Mucous cells
37. "Chief cells" or "Zymogen cells" secrete the enzymes of the gastric juice, are found in the [CBSE PMT 1992]  
 (a) Isthmus of the gland  
 (b) Neck of the tubular gland  
 (c) Base of the tubular region  
 (d) All the above
38. Inner lining of gut, stomach and liver is composed of [AFMC 1997]  
 (a) Simple squamous epithelium  
 (b) Simple columnar epithelium  
 (c) Simple cuboidal epithelium  
 (d) Compound epithelium
39. The mucosal lining of the oesophagus of mammals is made up of [MP PMT 1997]  
 (a) Simple columnar epithelium  
 (b) Squamous epithelium  
 (c) Stratified cuboidal epithelium  
 (d) Stratified columnar epithelium
40. Submucosa is thickest in [MP PMT 1998]  
 (a) Stomach (b) Oesophagus  
 (c) Intestine (d) Rectum
41. Which one of the following is the correct pairing of the site of action and the substrate of rennin [CBSE PMT 1994]  
 (a) Stomach-Casein  
 (b) Stomach-Fat  
 (c) Small intestine-Protein  
 (d) Mouth-Starch
42. The site of protein digestion is [NCERT; KCET 1994; MP PMT 2012]  
 Or  
 A rabbit eats a lot of gram. Then its digestion starts in [RPMT 2001]  
 (a) Gullet (b) Stomach  
 (c) Small intestine (d) Oral cavity
43. The stomach of ruminants is mainly divided into four parts, but in camel which one part is missing  
 (a) Abomasum (b) Omasum  
 (c) Reticulum (d) Rumen

44. Match column I with column II and choose the correct option

Column I		Column II	
A.	Goblet cells	1.	Antibacterial agent
B.	Lysozyme	2.	Mucus
C.	Saliva	3.	HCl
D.	Oxyntic cells	4.	Sublingual gland

[NCERT; MP PMT 2000; Kerala PMT 2010]

- (a) A-3, B-1, C-4, D-2 (b) A-1, B-3, C-4, D-2  
(c) A-2, B-3, C-1, D-4 (d) A-4, B-1, C-2, D-3  
(e) A-2, B-1, C-4, D-3
45. During chain elongation peptide bond is formed between carboxyl group of 1st amino acid and amino group of 2nd amino acid by [Odisha JEE 2010]  
(a) Aminoacyl transferase (b) Aminoacyl synthetase  
(c) Peptidyl transferase (d) Chloramphenicol
46. Peyer's patches contain [MP PMT 1996; Pb. PMT 2004]  
(a) Mucus (b) Sebum  
(c) Lymphocytes (d) Red blood cells
47. Narrower distal end of stomach is called [NCERT; MP PMT 1994, 95]  
(a) Cardiac (b) Duodenum  
(c) Pharynx (d) Pylorus
48. Aggregates of lymphoid tissue present in the distal portion of the small intestine are known as [DUMET 2010]  
(a) Villi (b) Peyer's patches  
(c) Rugae (d) Choroid plexus
49. Wisdom teeth are [AFMC 2005]  
(a) Last molars (b) Last premolars  
(c) Incisors (d) Canines
50. Peyer's patches are found on the ileum in [CBSE PMT 1993]  
(a) Fishes (b) Reptiles  
(c) Birds (d) Mammals
51. Water is largely absorbed in [NCERT; CPMT 1999, 2005]  
(a) Stomach (b) Oesophagus  
(c) Small intestine (d) Colon (Large Intestine)
52. Crypts of Lieberkuhn are found in between the villi. They secrete [MP PMT 2003, 06]  
(a) Glucagon (b) Succus entericus  
(c) Insulin (d) None
53. Both the crown and root of a tooth is covered by a layer of bony hard substance called [J & K CET 2005]  
(a) Enamel (b) Dentine  
(c) Bony socket (d) Cementum
54. Which of the following nerves innervates alimentary canal [Odisha JEE 2010]  
(a) Oculomotor (b) Abducens  
(c) Trigeminal (d) Vagus
55. Goblet cells are [NCERT; MP PMT 2012]  
(a) Unicellular mucous gland  
(b) Multicellular mucous gland of stomach  
(c) Tubula-veolar gland  
(d) All of the above

56. Which of the following is correct regarding diastema

[Odisha JEE 2010]

- (a) Gap between bones  
(b) Gap between the teeth/Absence of certain teeth  
(c) Gap between nerves  
(d) Gap between cells
57. Brunner's gland are found in which of the following layers [NCERT; CBSE PMT 1992, 99; CPMT 1993, 99; MP PMT 1998, 2001, 03; AFMC 2003, 08, 10; BHU 2012; WB JEE 2012, 16]  
(a) Submucosa of stomach  
(b) Mucosa of ileum  
(c) Submucosa of duodenum (intestine)  
(d) Mucosa of oesophagus
58. Pepsinogen is secreted by [NCERT; CPMT 1993; MP PMT 2003; DPMT 2007]  
(a) Chief cells (b) Parietal cells  
(c) Gastric glands (d) Intestinal cells
59. Intestinal villi are mainly concerned with [MP PMT 1994; MHCET 2001]

Or

The process by which digested food of the alimentary canal passes through its mucous membrane into circulatory system is called as [AIIMS 1992]

- (a) Assimilation (b) Secretion  
(c) Ultrafiltration (d) Absorption
60. Crypt of Lieberkuhn is example for [Kerala CET 2003]  
(a) Simple tubular gland  
(b) Coiled tubular gland  
(c) Compound alveolar gland  
(d) Compound tubular gland
61. Brush bordered epithelium is found in [CPMT 1999; JIPMER 2001]  
(a) Trachea (b) Stomach  
(c) Small intestine (d) Fallopian tube
62. Vermiform appendix is a part of [MP PMT 1994, 95]  
(a) Alimentary canal (b) Nervous system  
(c) Vascular system (d) Reproductive system

### Digestive glands

1. How many kinds of cells are found in islet of Langerhans [MP PMT 1997]  
(a) 1 (b) 2  
(c) 3 (d) 4
2. Which of the following statement is not correct [AIPMT (Cancelled) 2015]  
(a) Goblet cells are present in the mucosa of intestine and secrete mucus  
(b) Oxyntic cells are present in the mucosa of stomach and secrete HCl  
(c) Acini are present in the pancreas and secrete carboxypeptidase  
(d) Brunner's glands are present in the submucosa of stomach and secrete pepsinogen

3. Fat digestion is facilitated by [CPMT 1998]
  - (a) Bile juice (b) Pancreatic juice
  - (c) Gastric juice (d) None of these
4. The predominant antibody in saliva is [DUMET 2010]
  - (a) IgG (b) IgA
  - (c) IgM (d) IgD
5. In man, Glisson's capsule is associated with the [Kerala PMT 2012]
  - (a) Digestive system (b) Excretory system
  - (c) Nervous system (d) Reproductive system
  - (e) Endocrine system
6. Parotid salivary gland are present [NCERT; MP PMT 1993]
  - (a) Below the tongue
  - (b) Below the ear
  - (c) Below the eye orbit
  - (d) In the angle between two jaws
7. Pissiform cells loaded with zymogen granules can be seen in [MP PMT 1993]
  - (a) Liver (b) Pancreas
  - (c) Ovary (d) Kidney
8. Pancreatic juice contains [NCERT]
  - (a) Trypsin, lipase and maltase
  - (b) Pepsin, trypsin and maltase
  - (c) Trypsin, chymotrypsin, amylase and lipase
  - (d) Trypsin, pepsin and amylase
9. Gastric juice of infants contains [AIPMT (Cancelled) 2015]
  - (a) Nuclease, pepsinogen, lipase
  - (b) Pepsinogen, lipase, rennin
  - (c) Amylase, rennin, pepsinogen
  - (d) Maltase, pepsinogen, rennin
10. Ptyalin is [AFMC 1996]
  - (a) Strongly acidic (b) Slightly acidic
  - (c) Slightly neutral (d) Strongly alkaline
11. Liver in our body stores [AIIMS 1999]
  - (a) Vitamin A (b) Vitamin D
  - (c) Vitamin B<sub>12</sub> (d) All of these
12. Argentaffin cells are found in [NCERT; BHU 1999; AMU (Med.) 2012]
  - (a) Pancreas (b) Internal ear
  - (c) Gastric glands (d) Liver
13. pH of gastric juice is [Odisha JEE 2008; MP PMT 2010]
  - (a) 2 (b) 4
  - (c) 6 (d) 8
14. Which of the following guards the opening of hepatopancreatic duct into the duodenum [NEET (Phase-I) 2016]
  - (a) Semilunar valve (b) Ileocaecal valve
  - (c) Pyloric sphincter (d) Sphincter of Oddi
15. In pancreas, pancreatic juice and hormones are secreted by [CBSE PMT 1990]
  - (a) Same cells
  - (b) Different cells
  - (c) Same cells at different times
  - (d) None of these
16. The pH of amylase present in saliva is [NCERT; CPMT 1996]
  - (a) 6 (b) 6.8
  - (c) 7.2 (d) 8
17. Characteristic of mammalian liver is [AFMC 2006]
  - (a) Kupffer's cells and leucocytes
  - (b) Leucocytes and canaliculae
  - (c) Glisson's capsules and Kupffer cells
  - (d) Glisson's capsules and leucocytes
18. The pH of succus entericus is [MP PMT 1996]
 

Or

In intestine, pH value is

  - (a) 7.6 (b) 6.6
  - (c) 5.6 (d) 2.0
19. Succus entericus is the name given to [NCERT]
  - (a) Junction between ileum and large intestine
  - (b) Intestinal juice
  - (c) Swelling in the gut
  - (d) Appendix
20. Liver of rabbit is made up of
  - (a) 4 lobes (b) 6 lobes
  - (c) 5 lobes (d) 7 lobes
21. Which of the following statements is correct [CPMT 2010]
  - (a) Argentaffin cells produce serotonin
  - (b) Villikinin is secreted by large intestine
  - (c) In cheilosis, deficiency nutrient is nicotinamide
  - (d) Bleeding diseases occur due to deficiency of vitamin E
22. Which of the following is the symptom of Ulcerative colitis [GUJCET 2015]
  - (a) Watery stools containing blood and mucus
  - (b) Difficulty in swallowing
  - (c) Loss of appetite
  - (d) Eyes turn yellow
23. Which one of the following is not the reason for very high load of bilirubin in a newborn [KCET 2010]
  - (a) Excessive red blood corpuscles in the newborn burst, releasing the bilirubin
  - (b) The liver of the newborn is too young to cope up with the heavy load of bilirubin
  - (c) Mother's milk contain a high amount of bilirubin
  - (d) Insoluble bilirubin in the intestine is reabsorbed by the blood
24. Saliva is secreted from [NCERT; MP PMT 1998]
  - (a) Submaxillary and sublingual glands
  - (b) Gastric gland
  - (c) Pancreas
  - (d) Gall bladder
25. The number of salivary glands in man is [NCERT]
  - (a) Two pairs (b) Three pairs
  - (c) Four pairs (d) Five pairs

26. Ptyalin is an enzyme of  
[CMC Vellore 1992; MP PMT 1994, 99;  
CPMT 2003; MH CET 2004; Odisha JEE 2011]

(a) Salivary juice (b) Pancreatic juice  
(c) Intestinal juice (d) None of these

27. The enzymes responsible for the digestion of starch in food of man is present in

(a) The salivary and gastric secretions  
(b) The salivary and pancreatic secretions  
(c) The gastric and pancreatic secretions  
(d) The gastric and duodenal secretions

28. A lubricant, mucin in saliva is made up of [Pb. PMT 2004]

(a) Glycoprotein (b) Polysaccharides  
(c) Phospholipids (d) Myosin

29. The toxic substance are detoxicated in the human body by  
[AIIMS 2001]

(a) Lungs (b) Kidneys  
(c) Liver (d) Stomach

30. The trypsin enzyme is secreted by [AFMC 2003]

(a) Stomach (b) Duodenum  
(c) Pancreas (d) Liver

31. Bilirubin and biliverdin are found in [NCERT; MP PMT 2001]

(a) Blood (b) Bile  
(c) Pancreatic juice (d) Saliva

32. Match the names of glands listed under column-I with the location given under column-II, choose the answer which gives correct combination of the alphabets of the two columns

Column-I (glands)		Column-II (location)	
A.	Crypts of Lieberkuhn	p.	Loop of duodenum
B.	Pancreas	q.	Stomach
C.	Adrenal gland	r.	Intestine
D.	Gastric gland	s.	Kidney

[KCET 2001; Kerala PMT 2008]

- (a) A = r, B = p, C = q, D = s  
(b) A = r, B = p, C = s, D = q  
(c) A = q, B = s, C = r, D = p  
(d) A = p, B = r, C = s, D = q

33. The bile secreted by the liver cells passes into the gall bladder through [NCERT; DPMT 1993]

(a) Hepato-pancreatic duct (b) Cystic duct  
(c) Hepatic duct (d) Hepato-gall duct

34. Which of the following is not a human salivary gland [NCERT; AIIMS 1993]

(a) Parotid (b) Submaxillary  
(c) Sublingual (d) Infra-orbital

35. Which is correct about the bile of rabbit [NCERT; RPMT 2002]

(a) It is synthesized by gall bladder & also stored there  
(b) It is an enzyme which emulsify the fats  
(c) It contain bile salts & bile pigments  
(d) Bilirubin present in it decomposed fats

36. Which of the following digestive juices have the minimum pH [AIIMS 2002]

(a) Bile (b) Saliva  
(c) Gastric juice (d) Pancreatic juice

37. In which of the following, putrefying bacteria is present [BHU 2006]

(a) Intestine (b) Colon  
(c) Stomach (d) Liver

38. The glucose is converted into glycogen in liver and stored in [MP PMT 1994, 95; CPMT 1995]

(a) Liver (b) Liver and muscles  
(c) Liver and spleen (d) Spleen and muscles

39. Gastric juice contains [NCERT; CPMT 1993; Kerala PMT 2010; MP PMT 2011]

(a) Pepsin, rennin, lipase (b) Pepsin, amylase, rennin  
(c) Pepsin, amylase, trypsin (d) Lipase, rennin, trypsin

40. Enzyme arginase is found in [CPMT 1994]

(a) Mouth cavity (b) Stomach  
(c) Intestine (d) Liver

41. A your infant may be feeding entirely on mother's milk which is white in colour but the stools which the infant passes out is quite yellowish. What is this yellow colour due to [CBSE PMT 2009]

(a) Intestinal juice  
(b) Bile pigments passed through bile  
(c) Undigested milk protein casein  
(d) Pancreatic juice poured into duodenum

42. Kupffer cells of liver are [JIPMER 2001; MP PMT 2001, 02; BVP 2002; CPMT 2003; BHU 2008; WB JEE 2011]

(a) Loose connective tissue (b) Phagocytic cell  
(c) Mast cell (d) Fat cell

43. Bile secretion is proportional to the concentration of [MP PMT 2007]

(a) Protein (b) Fat  
(c) Carbohydrate (d) None of these

44. The special feature of bile juice is that it [NCERT; Odisha JEE 2011]

(a) Has no enzyme (b) Has amylase  
(c) Contains lipase (d) Contains  $H_2O$

45. Cells of the liver manufacture [DPMT 1993]

(a) Diastase (b) Amylase  
(c) Lipase (d) Insulin

46. Succus entericus is secreted by [KCET 2007, 10]

(a) Islets of Langerhans  
(b) Gastric gland  
(c) Uterine crypt and endometrium  
(d) Crypts of Lieberkuhn and Brunner's gland

47. In which of the following proteins are absent [MP PMT 2000]

(a) Pancreatic juice (b) Saliva  
(c) Bile (d) Intestinal juice

48. Which word best describes the action of bile on fats  
[CBSE PMT 1993; BHU 2003; DUMET 2010; Odisha JEE 2010]  
(a) Neutralises (b) Digests  
(c) Emulsifies (d) Absorbs  
(e) Dissolves
49. pH of the pancreatic juice is about  
(a) 6.4 (b) 8.4  
(c) 12.0 (d) 7.0
50. One of the following is specific function of the liver. Mark it  
[WB JEE 2008]  
(a) Excretion (b) Glycogenolysis  
(c) Digestion (d) Histolysis
51. Surgical removal of gall bladder in human beings would lead to  
[AIIMS 1992; CBSE PMT 1992]  
(a) Impairment of the digestion of fat  
(b) Increased acidity in the intestine  
(c) Jaundice  
(d) None of the above
52. Which one of the following does not produce any digestive enzyme  
[NCERT; DPMT 1992]  
(a) Intestinal mucosa (b) Gastric mucosa  
(c) Pancreas (d) Liver
53. Kupffer cells are found in  
[CPMT 1999, 2003; Bihar MDAT 1995; JIPMER 2000, 01; MP PMT 2000, 01, 02; BHU 2006; WB JEE 2016]  
(a) Mouth (b) Liver  
(c) Kidney (d) Stomach
54. Which one of the following pairs of the kind of cells and their secretion of correctly matched  
[AIIMS 2008]  
(a) Oxyntic cells - A secretion with pH between 2.0 and 3.0  
(b) Alpha cells of islets - Secretion that decreases blood sugar level  
(c) Kupffer cells - A digestive enzyme that hydrolyses nucleic acids  
(d) Sebaceous glands - A secretion that evaporates for cooling
55. Liver is called the reticular gland because  
[DPMT 1993]  
(a) The shape is reticular  
(b) It contains reticular tissue  
(c) Lobules branches and anastomose with one another to form a network  
(d) Hepatic duct and cystic duct unite to form the bile duct
56. Enterokinase and lactase are found in  
[CPMT 2000; MP PMT 2000]  
(a) Saliva (b) Bile  
(c) Pancreatic juice (d) Intestinal juice
57. The largest gland in the human body is  
[NCERT; KCET 2000; CPMT 2000; BVP 2002; BHU 2006]  
(a) Liver (b) Brain  
(c) Pancreas (d) Thyroid
58. Cholesterol is synthesised in  
[MP PMT 1993, 2000]  
(a) Pancreas (b) Brunner's gland  
(c) Spleen (d) Liver

59. Match the types of cells listed under column I with the secretions given under column II. Choose the answer which gives the correct combination of the alphabets of the two columns

Column I (Types of cells)		Column II (Secretions)	
A.	Beta cells	p.	Lysozyme
B.	Mast cells	q.	Histamine
C.	Paneth cells	r.	Insulin
D.	Acinar cells	s.	Pancreatic enzymes

[KCET 2004]

- (a) A = r; B = s; C = p; D = q (b) A = s; B = q; C = p; D = r  
(c) A = r; B = q; C = p; D = s (d) A = q; B = r; C = p; D = s
60. Caudate is the part of  
(a) Left lobe of liver (b) Right lobe of liver  
(c) Spigelian lobe of liver (d) All of the above
61. Amount of saliva secreted daily in humans is  
[NCERT; Odisha JEE 2004; AMU (Med.) 2012]  
(a) 250 ml. (b) 500 ml.  
(c) 100 ml. (d) 1000 ml.
62. Lysozymes are found in [MP PMT 2004; Odisha JEE 2010]  
(a) Saliva (b) Tears  
(c) Saliva and tears both (d) Mitochondria
63. The amount of gastric juice secreted per day from man's stomach is about [MP PMT 2003]  
(a) 5000 ml to 10000 ml (b) 2000 ml to 3000 ml  
(c) 100 ml to 500 ml (d) 10 ml to 15 ml
64. Which cells of 'Crypts of Lieberkuhn' secrete antibacterial lysozyme [NEET 2017]  
(a) Argentaffin cells (b) Paneth cells  
(c) Zymogen cells (d) Kupffer cells

### Physiology of digestion

1. Fructose is absorbed into the blood through mucosa cells of intestine by the process called [NCERT; CBSE PMT 2014]  
(a) Simple diffusion (b) Co-transport mechanism  
(c) Active transport (d) Facilitated transport
2. Which one of the following pairs of food components in humans reaches the stomach totally undigested  
[CBSE PMT 2009]  
(a) Protein and starch (b) Fat and starch  
(c) Fat and cellulose (d) Starch and cellulose
3. In vertebrates, lacteals are found in [CBSE PMT 1998]  
(a) Ileum (b) Ischium  
(c) Oesophagus (d) Ear
4. If pancreas is removed, the compound which remain undigested is [CBSE PMT 1997]  
(a) Carbohydrates (b) Fats  
(c) Proteins (d) All of these
5. Chylomicrons are [NCERT; CPMT 1999]  
(a) Undigested proteins  
(b) Undigested carbohydrates  
(c) Fat droplets coated with glycerol and protein  
(d) Fat droplets coated with phospholipids

6. Which enzymes are likely to act on the baked potatoes eaten by a man, starting from the mouth and as it moves down the alimentary canal [NEET (Karnataka) 2013]  
 (a) Pancreatic amylase → salivary amylase → lipases  
 (b) Disaccharidase like maltase → lipases → nucleases  
 (c) Salivary amylase → pancreatic amylase → disaccharidases  
 (d) Salivary maltase → carboxy peptidase → trypsinogen
7. Trypsin is a digestive enzyme which occurs in mammals and digests [CPMT 1992, 93; MP PMT 1995]  
 (a) Starch in buccal cavity in an alkaline medium  
 (b) Protein in stomach in an acidic medium  
 (c) Protein in duodenum in an acidic medium  
 (d) Protein in duodenum in an alkaline medium
8. The major site of protein breakdown to form free amino acids, is in the [WB JEE 2009]  
 (a) Kidney (b) Spleen  
 (c) Liver (d) Bone-marrow
9. The first phase in the breakdown of glucose in animal cell is [CBSE PMT 1994]  
 (a) Glycolysis (b) Electron transport system  
 (c) Fermentation (d) Kreb's cycle
10. Digestion of both starch and protein is done by [NCERT; AFMC 1996]  
 (a) Gastric juice (b) Gastric lipase  
 (c) Pancreatic juice (d) Ptylin
11. The end product of carbohydrate metabolism is [AFMC 1993]  
 (a)  $\text{CO}_2$  and  $\text{H}_2\text{O}$  (b)  $\text{NH}_3$  and  $\text{CO}_2$   
 (c)  $\text{NH}_3$  and  $\text{H}_2\text{O}$  (d)  $\text{CO}_2$
12. Which one of the following statements about glycogen is correct [CBSE PMT 1995]  
 (a) It is a disaccharide stored in liver which can react with ammonia to form proteins  
 (b) It is synthesised in the liver and takes part in the formation of bile and lipase, besides being a source of energy  
 (c) It is a polysaccharide which is synthesised and stored in liver cells  
 (d) It is synthesised in blood and stored in liver and muscles to provide glucose in times of need
13. Which one of the following statements is true regarding digestion and absorption of food in humans [CBSE PMT 2009]  
 (a) Oxyntic cells in our stomach secrete the proenzyme pepsinogen  
 (b) Fructose and amino acids are absorbed through intestinal mucosa with the help of carrier ions like  $\text{Na}^+$   
 (c) Chylomicrons are small lipoprotein particles that are transported from intestine into blood capillaries  
 (d) About 60% of starch is hydrolysed by salivary amylase in our mouth
14. Fats and lipids are absorbed in [AFMC 2008]  
 (a) Lymph capillaries (b) Blood capillaries  
 (c) Hepatic portal vein (d) None of these
15. One of the following movements in our body is not completely involuntary. Identify it [KCET 2012]  
 (a) Deglutition (b) Peristalsis  
 (c) Systole of the ventricles (d) Dilation of pupil of the eye
16. In the gastrointestinal tract the Meissner's plexus and the Auerbach's plexus occur respectively in the [NCERT; AMU (Med.) 2012]  
 (a) Lamina propria and muscularis mucosa  
 (b) Submucosa and muscularis externa  
 (c) Submucosa and mucosa  
 (d) Mucosa and muscularis externa
17. Emulsified fat is digested by [AFMC 1996]  
 Or  
 Bile salts act as activator of which enzyme [WB JEE 2010]  
 (a) Lipase (b) Lipase and hydrolase  
 (c) Bile salts (d) Bile pigments
18. Lacteals are found in [NCERT; MP PMT 1999; KCET 2004]  
 (a) Liver (b) Lungs  
 (c) Kidney (d) Villus of intestine
19. Which one of the following is the correct matching of the site of action on the given substrate, the enzyme acting upon it and the end product [NCERT; CBSE PMT 2008]  
 (a) Small intestine : —————> Proteins Pepsin Amino acids  
 (b) Stomach : —————> Fats Lipase micelles  
 (c) Duodenum : —————> Triglycerides Trypsin monoglycerides  
 (d) Small intestine : —————> Starch  $\alpha$ -Amylase Disaccharide (Maltose)
20. If for some reason the parietal cells of the gut epithelium become partially non-functional, what is likely to happen [NCERT; CBSE PMT (Malna) 2010]  
 (a) The pancreatic enzymes and specially the trypsin and lipase will not work efficiently  
 (b) The pH of stomach will fall abruptly  
 (c) Steapsin will be more effective  
 (d) Proteins will not be adequately hydrolysed by pepsin into proteoses and peptones
21. Which of the following is secreted by pancreas [Odisha JEE 2012]  
 (a) Dipeptidases (b) Amylase  
 (c)  $\alpha$ -Dextrins (d) Pepsin
22. Most digestion and absorption of food takes place in [NCERT; Odisha JEE 2009]  
 (a) Stomach (b) Small intestine  
 (c) Large intestine (d) Caecum
23. Essentially the word 'digestion' means [NCERT; CPMT 2005]  
 (a) Burning of food (b) Oxidation of food  
 (c) Hydrolysis of food (d) Breakdown of food



24. Emulsification of fats is brought about by  
[NCERT; CBSE PMT 1990; Manipal 2005]

(a) Bile pigments (b) Bile salts  
(c) Pancreatic juice (d) HCl

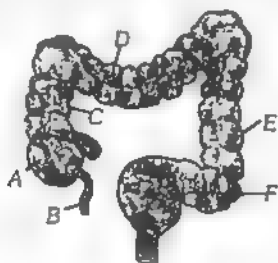
25. Saccus rotundus is present in [CPMT 2010]

(a) Duodenum of rabbit (b) Ileum of frog  
(c) Ileum of rabbit (d) Colon of rabbit

26. Which one of the following will not take place when glucose is taken as food [J & K CET 2002]

(a) Ingestion (b) Digestion  
(c) Absorption (d) Assimilation

27. The diagram of large intestine of man is given below. Identify the parts labelled A, B, C, D, E and F [KCET 2010]



A	B	C	D	E	F
(a) Sigmoid appendix	Vermiform colon	Ascending	Transverse	Descending	Caecum
(b) Caecum Vermiform appendix	Sigmoid	Ascending	Transverse	Descending	Colon
(c) Caecum Vermiform appendix	Ascending	Transverse	Descending	Sigmoid	Colon
(d) Sigmoid Vermiform appendix	Descending	Transverse	Ascending	Caecum	Colon

28. Some proteolytic enzymes are [NCERT; Odisha JEE 2010]

(a) Trypsin, Erepsin, pepsin  
(b) Amylopsin, steapsin, ptyalin  
(c) Amylase, lipase, zymase  
(d) Urease, zymase, dehydrogenase

29. Choose the wrong statement [Kerala PMT 2012]

(a) Lipases and nucleases are not present in pancreatic juice  
(b) Goblet cells secrete mucus  
(c) Brunner's glands are sub-mucosal glands  
(d) Carboxypeptidase catalyses conversion of proteins, peptones and proteoses to dipeptides  
(e) Bile contains no enzymes

30. Rennin acts on milk proteins and converts [JIPMER 2002]

(a) Caseinogen into casein  
(b) Casein into paracasein  
(c) Caseinogen into paracasein  
(d) Paracasein into caseinogen

31. Lacteals are associated with [DPMT 1993; MP PMT 2013]

(a) Secretion of lactic acid  
(b) Absorption of long chain fatty acids  
(c) Absorption of short chain fatty acids  
(d) Production of lymph

32. In gluconeogenesis [Pb. PMT 2000; DPMT 2003]

(a) Glucose is polymerized into glycogen  
(b) Glycogen is broken into glucose  
(c) Carbohydrates are synthesized from amino acids/lipids  
(d) Glucose is broken into pyruvic acid

33. Carrier ions like  $\text{Na}^+$  facilitate the absorption of substances like [CBSE PMT (Pre.) 2010]

(a) Fructose and some amino acids  
(b) Amino acids and glucose  
(c) Glucose and fatty acids  
(d) Fatty acids and glycerol

34. The pH of the digestive juices within the human small intestine is between 7.5 and 8.5. This environment is slightly [AIIMS 2009]

(a) Basic (b) Acidic  
(c) Neutral (d) None of these

35. Trypsin differs from pepsin in that [NCERT]

(a) It digest protein in alkaline medium while pepsin does so in acidic medium  
(b) It digest protein in acidic medium while pepsin does so in alkaline medium  
(c) Both (a) and (b)  
(d) None of these

36. Digestion of starch takes place in [NCERT; Kerala CET 2003]

(a) Stomach and duodenum  
(b) Buccal cavity and duodenum  
(c) Buccal cavity and oesophagus  
(d) Duodenum only

37. Ptyalin is inactivated by a component of gastric juice known as [WB JEE 2011]

(a) Pepsin (b) Mucus  
(c) Rennin (d) HCl

38. Function of HCl in stomach is to [MP PMT 1994; CPMT 1995; Odisha JEE 2012]

(a) Kill micro-organisms of food  
(b) Facilitate absorption of food  
(c) Dissolve enzymes  
(d) Activate pepsinogen to pepsin

39. Lipids, which can be found in oil based salad dressings and ice cream, during digestion are splitted into [NCERT; AIIMS 2009]

Or

The main function of Lacteals in the human small intestine is the absorption of [KCET 2006]

(a) Fatty acids and glycerol (b) Glycerol and amino acids  
(c) Glucose and fatty acids (d) Glucose and amino acids

40. In horses, rabbits, hares, the cellulose gets digested in the [CPMT 1994, 95, 2010; MP PMT 2000; AFMC 2005; RPMT 2006]

(a) Caecum (b) Stomach  
(c) Appendix (d) Rumen

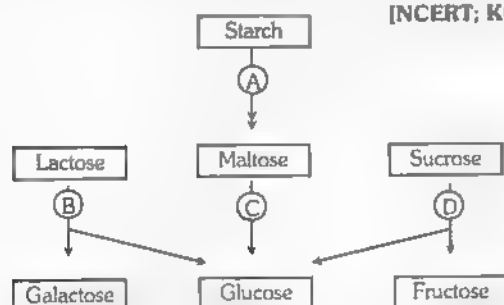
41. Part of the stomach which opens into the duodenum  
[NCERT; BHU 2008; Odisha JEE 2010]

(a) Cardiac (b) Pyloric  
(c) Fundus (d) Body

42. Energy released by carbohydrate, fats, protein is  
[NCERT; DPMT 2006]

(a) 4.1, 9.45, 5.65 (b) 4.1, 5.65, 9.40  
(c) 5.4, 6.5, 8.9 (d) 5.0, 7.8, 10.5

43. The following is a scheme showing the fate of carbohydrates during digestion in the human alimentary canal. Identify the enzymes acting at stages indicated as A, B, C and D. Choose the correct option from those given  
[NCERT; KCET 2006]



(a) A = amylase, B = maltase, C = lactase, D = invertase  
(b) A = amylase, B = maltase, C = invertase, D = lactase  
(c) A = amylase, B = invertase, C = maltase, D = lactase  
(d) A = amylase, B = lactase, C = maltase, D = invertase

44. The food that enters intestine from stomach is called  
[NCERT; AFMC 2008, 09]

(a) Chyle (b) Chyme  
(c) Fundus (d) None of these

45. End products of protein hydrolysis are  
[RPMT 2002; HPMT 2005]

(a) Mixture of amino acids (b) Sugars  
(c) Peptides (d) 25 amino acids

46. The amount of bile released in proportion to the amount of  
[CPMT 2004]

(a) Fat in meal (b) Protein in meal  
(c) Carbohydrate in meal (d) All of the above

47. Which one of the following is the matching pair of digestive enzyme and substrate  
[MP PMT 1992]

(a) Rennin-Protein (b) Amylase-Lactose  
(c) Trypsin-Starch (d) Invertase-Maltose

48. Digestion of which component of the food is likely to be most adversely affected if the pH of stomach is made neutral  
[MP PMT 1992]

(a) Sucrose (b) Starch  
(c) Protein (d) Fat

49. In man cellulose is digested in  
[CBSE PMT 1992; CPMT 1995]

(a) The caecum (b) The colon  
(c) The appendix (d) Not digested at all

50. Milk protein is acted upon by a gastric enzyme  
[NCERT; CBSE PMT 2000; AIIMS 2002; BCECE 2005]  
Or

Which one of the following enzyme carries on the initial step in the digestion of milk in humans  
[CBSE PMT (Pre.) 2011; CBSE PMT 2014]

(a) Casein (b) Rennin  
(c) Pepsin (d) Caseinogen

51. Bile salt [AMU (Med.) 2005]

(a) Acts as emulsifying agent  
(b) Helps in absorption of fatty acids, cholesterol etc.  
(c) Stimulates the bile production in liver  
(d) All of the above

52. Maltase converts [Odisha JEE 2005]

(a) Maltose to glucose at pH greater than 7  
(b) Maltose to glucose at pH less than 7  
(c) Maltose to alcohol  
(d) Starch to maltose at higher pH than 7

53. Duodenum has characteristic Brunner's glands which secrete two hormones called [CBSE PMT 2004, 05; KCET 2012]

(a) Prolactin, parathormone (b) Estradiol, progesterone  
(c) Kinase, estrogen (d) Secretin, cholecystokinlin

54. The function of erepsin in the process of digestion is to convert

(a) Fats into amino acids  
(b) Proteins in amino acids  
(c) Polysaccharides into disaccharides  
(d) Disaccharides into monosaccharides

55. Just as hydrochloric acid is to pepsinogen, so is  
[MP PMT 2004]

(a) Enterokinase to trypsinogen  
(b) Haemoglobin to oxygen  
(c) Bile juice to fat  
(d) Glucagon to glycogen

56. In ileum which of the following is absorbed [CPMT 2009]

(a) Vitamin K (b) Bile salt  
(c) Glucose (d) Fat

57. Bile salts are poured into the alimentary canal where they are necessary for the absorption of

(a)  $\text{Na}^+$  and  $\text{Ca}^{++}$   
(b) Fat soluble vitamins  
(c) Amino acids and monosaccharides  
(d) All the nutrients contained in chyme

58. Fatty substances are emulsified by [WB JEE 2016]

(a) Lipase enzyme  
(b) Bilirubin and biliverdin  
(c) HCl  
(d) Sodium salts of glycocholic and taurocholic acids

59. Which of the following option best represents the enzyme composition of pancreatic juice [NEET 2017]

(a) Amylase, peptidase, trypsinogen, rennin  
(b) Amylase, pepsin, trypsinogen, maltase  
(c) Peptidase, amylase, pepsin, rennin  
(d) Lipase, amylase, trypsinogen, procarboxypeptidase

### Gastro intestinal hormones/Digestive enzymes

1. What will happen if the secretion of parietal cells of gastric glands is blocked with an inhibitor [CBSE PMT 2008]

(a) In the absence of HCl secretion, inactive pepsinogen is not converted into the active enzyme pepsin  
(b) Enterokinase will not be released from the duodenal mucosa and so trypsinogen is not converted to trypsin  
(c) Gastric juice will be deficient in chymosin  
(d) Gastric juice will be deficient in pepsinogen

2. Pancreatic secretion and gall bladder contraction are stimulated by [AFMC 1993, 2005; CBSE PMT 1998; BHU 1999; AIIMS 2000; CPMT 2003; DPMT 2006; MP PMT 2010]
- Gastrin
  - Enterocrinin
  - Enterogastrone
  - Cholecystokinin pancreozymin
3. Digestion is brought about by [Odisha JEE 2009]
- Hormones
  - Neurotransmitters
  - Growth factors
  - Enzymes
4. Salivary amylase, a digestive enzyme begins digestion of [Odisha JEE 2009; MP PMT 2010]
- Proteins
  - Fats
  - Carbohydrates
  - All of these
5. One of the constituents of the pancreatic juice while poured into the duodenum in humans, is [CBSE PMT (Mains) 2011]
- Or
- Which is same as propepsin [CPMT 1994]
- Trypsin
  - Enterokinase
  - Trypsinogen
  - Chymotrypsin
6. Match list I with list II and choose the correct option
- | List I               | List II                    |
|----------------------|----------------------------|
| (A) Salivary amylase | (1) Proteins               |
| (B) Bile salts       | (2) Milk proteins          |
| (C) Rennin           | (3) Starch                 |
| (D) Pepsin           | (4) Lipids                 |
| (E) Steapsin         | (5) Emulsification of fats |
- [NCERT; Kerala PMT 2009]
- (A) — (5), (B) — (4), (C) — (1), (D) — (2), (E) — (3)
  - (A) — (2), (B) — (3), (C) — (4), (D) — (5), (E) — (1)
  - (A) — (2), (B) — (4), (C) — (3), (D) — (1), (E) — (5)
  - (A) — (3), (B) — (5), (C) — (2), (D) — (1), (E) — (4)
  - (A) — (3), (B) — (5), (C) — (1), (D) — (2), (E) — (4)
7. Which of the following statement is correct [AIIMS 1993]
- Though secretin is an enzyme, it is not involved in digestion
  - Secretin is an enzyme and so it helps digestion
  - Secretin is a hormone but it plays a role in digestion
  - Secretin is a hormone and hence it does not play any role in digestion
8. The enzyme added to the starch solution may have been [CPMT 1992, 93]
- Maltase
  - Invertase
  - Lipase
  - Amylase
9. Enzymes which acts similarly are called as [CPMT 1995]
- Isoenzymes
  - Cofactor
  - Coenzymes
  - All the above
10. Zymogen cells and chief cells secrete [CBSE PMT 1990; CPMT 1994]
- Hydrochloric acid
  - Mucus
  - Pepsin
  - Trypsin
11. If this enzyme were to be absent in our small intestine, digestion of proteins in our body would be severely affected [GUJCET 2007; KCET 2009, 12]
- Pancreatic amylase
  - Maltase
  - Lipase
  - Enterokinase
12. Prorennin is secreted by [DPMT 2007]
- Zymogene cells
  - Islet of langerhans
  - Sertoli cells
  - Hepatocytes
13. Enzyme Rennin is secreted by [MP PMT 2001]
- Cells of stomach
  - Cells of intestine
  - The cortical cells of kidney
  - The cells of juxtaglomerular apparatus of kidney
14. The digestive enzyme that is not found in human pancreatic juice is [Kerala PMT 2006]
- Nucleotidase
  - Nuclease
  - Trypsin
  - Lipase
  - Amylase
15. Deoxyribonuclease, ribonuclease and Carboxypeptidase are secreted by [BHU 2003; Kerala PMT 2004]
- Liver
  - Stomach
  - Pancreas
  - Kidney
16. Bile synthesis occurs in [NCERT; MP PMT 1994; J & K CET 2002; Bihar CECE 2006]
- Liver
  - Duodenum
  - Pancreas
  - Stomach
17. Which one of the following four secretions is correctly matched with its source, target and nature of action [AIIMS 2005]
- |     | Secretion                       | Source                                  | Target                           | Action  |
|-----|---------------------------------|---|----------------------------------|---|
| (a) | Gastrin                         | Stomach lining                          | Oxyntic cells                    | Production of HCl   |
| (b) | Inhibin                         | Sertoli cells                           | Hypothalamus                     | Inhibition of secretion of gonadotropin releasing hormone |
| (c) | Enterokinase                    | Duodenum                                | Gall bladder                     | Release of bile juice                                     |
| (d) | Atrial Natriuretic Factor (ANF) | Sino atrial node (SAN) M-cells of Atria | Juxta-glomerular apparatus (JGA) | Inhibition of release of renin                            |
18. Which one of the following enzymes initiates protein digestion [MP PMT 1997; Bihar CECE 2006; GUJCET 2014]
- Or
- Which of the following digest proteins and peptides [HP PMT 2005]
- Aminopeptidase
  - Carboxypeptidase
  - Trypsin
  - Pepsin
19. Pepsin is produced by [MP PMT 1995, 98, 2006]
- Salivary glands
  - Stomach
  - Duodenum
  - Small intestine
20. Which one of the following is the correct match of digestive enzyme and substrate [CBSE PMT 1996]
- Lactose—Renin
  - Starch—Maltose
  - Fat—Steapsin
  - Casein—Trypsin
21. Glucagon secreted by the alpha-cells of the islets of Langerhans does this function [CPMT 1993; KCET 1994; MP PMT 2000; GUJCET 2014]
- Glucagon converts glucose into glycogen and increases the concentration of blood sugar
  - Glucagon converts glycogen into glucose and increases the concentration of blood sugar
  - Glucagon converts glucose into glycogen
  - None of these

22. Match the following and choose the correct combination from the options given

Column I		Column II	
A.	Ptyalin	1.	Lipids
B.	Pepsin	2.	Starch
C.	Steapsin	3.	DNA
D.	Nuclease	4.	Proteins

[MP PMT 1994; Kerala PMT 2004]

- (a) A-1, B-3, C-2, D-4 (b) A-1, B-4, C-3, D-2  
(c) A-2, B-4, C-1, D-3 (d) A-2, B-3, C-1, D-4  
(e) A-4, B-3, C-1, D-2
23. Cells of the pancreas is not digested by their own enzymes because [MP PMT 2003]  
(a) Enzymes are secreted in inactive form  
(b) Cells are not lined by mucous membrane  
(c) Enzymes are released only when needed  
(d) None of the above
24. When fat is in the stomach the secretion of gastrin is inhibited. This inhibition is due to [CPMT 1992]  
(a) Presence of fat (b) Non-stimulation of vagus  
(c) Slow digestion of fat (d) Release of enterogastron
25. Which of the following hormone stimulates the secretion of gastric juice [CMC Vellore 1993; CPMT 2002; BHU 2003; WB JEE 2010]

Or

Which of the following hormone helps in secretion of HCl from stomach [WB JEE 2008, 11]

- (a) Secretin (b) Gastron  
(c) Cholecystokinin (d) Gastrin

26. Cholecystokinin is a secretion of [MP PMT 1992; WB JEE 2012]  
(a) Stomach which stimulates pancreas to release the pancreatic juice  
(b) Liver synthesised from cholesterol and controls secondary sexual characters  
(c) Duodenum and makes the gall bladder to contract and release bile  
(d) Goblet cells of ileum and stimulates the secretion of succus entericus

27. In rabbit proteins are digested by [CPMT 1995]  
(a) Pepsin and trypsin (b) Trypsin and steapsin  
(c) Steapsin and pepsin (d) All the above

28. Which of the following is not a proteolytic enzyme [Bihar MDAT 1995]

Or

Which of the following belongs to the class of pepsin and trypsin

Or

Enzyme released from kidney is [AFMC 2008]

- (a) Pepsin (b) Trypsin  
(c) Erepsin (d) Renin

29. Identify the correct set which shows the name of the enzymes from where it is secreted and substrate upon which it acts [Odisha PMT 2002]

- (a) Pepsin-stomach wall- casein  
(b) Ptyalin- intestine-maltose  
(c) Chymotrypsin- salivary gland-lactose  
(d) Ptyalin - pancreas-lipid CoA

30. Trypsin converts [MP PMT 1995]

- (a) Fats into fatty acids  
(b) Starch and glycogen into maltose  
(c) Proteins into peptones  
(d) Sucrose into glucose and fructose

31. Islets of Langerhans produce [MP PMT 1995]

- (a) Insulin (b) Rennin  
(c) Ptyalin (d) HCl

32. Which of the following is a gastro-intestinal enzyme [AFMC 1997; WB JEE 2011]

- (a) Cholinestrace (b) Enterokinase  
(c) Secretin (d) Prolactin

33. Secretin [AMU (Med.) 2009]

- (a) Stimulates enzyme secretion by pancreas, inhibits acid secretion in stomach, stimulates gall bladder  
(b) Stimulates bicarbonate secretion by pancreas, inhibits acid secretion in stomach, stimulates bicarbonate secretion by liver  
(c) Stimulates acid secretion in stomach, potentiates action of CCK, inhibits intestinal movement  
(d) Stimulates gall bladder, inhibits acid secretion in stomach, stimulates bicarbonate secretion by pancreas

34. The gastrointestinal hormone which stimulates insulin secretion is [AMU (Med.) 2012]

- (a) Gastrin (b) CCK  
(c) Secretin (d) GIP

35. Gastric enzymes are [CPMT 2009]

- (a) Pepsinogen (b) Prorennin  
(c) Gastric lipase (d) All of these

36. Enzymes, vitamins and hormones can be classified into a single category of biological chemicals, because all of them [AIIMS 1992; CBSE PMT 2005]

- (a) Are proteins  
(b) Enhance the oxidative metabolism  
(c) Aid the regulating mechanism  
(d) Are synthesised within the body of an organism

37. The hormone 'secretin' stimulates secretion of [CBSE PMT 1990; MP PMT 1996, 2002, 07, 12; Pb. PMT 1999, 2000; BHU 2000]

- (a) Pancreatic juice (b) Bile juice  
(c) Salivary juice (d) Gastric juice

38. What is common among amylase, rennin and trypsin  
[CBSE PMT 1997; Pb. PMT 1999, 2000; BHU 2001]  
(a) These all are proteins  
(b) These all are proteolytic enzymes  
(c) These are produced in stomach  
(d) These act at a pH lower than 7
39. Cholecystokinin and duocrinin are secreted by  
[CBSE PMT 1999; AIEEE Pharmacy 2003]  
(a) Intestine (b) Pancreas  
(c) Adrenal cortex (d) Thyroid gland
40. Which part of body secretes the hormone secretin  
[MP PMT 1994, 95; CBSE PMT 1999; AIEEE Pharmacy 2003]  
(a) Ileum (b) Stomach  
(c) Duodenum (d) Oesophagus
41. What is the substrate for lipase enzyme [WB JEE 2012]  
(a) Protein (b) Carbohydrate  
(c) Lipid (d) Nucleic acid
42. Which of the following hormones induce secretion of succus entericus [RPMT 2000]

Or

Which hormones do stimulate the production of pancreatic juice and bicarbonate [NEET (Phase-II) 2016; WB JEE 2016]

- (a) Insulin  
(b) Secretin and cholecystokinin  
(c) Glucagon  
(d) Secretin
43. What is cholecystokinin [Odisha PMT 2002]  
(a) Enzyme (b) Bile-pigment  
(c) Gastro-intestinal hormone (d) Lipid

### Nutrition and Nutritional requirement

1. When breast feeding is replaced by less nutritive food low in proteins and calories; the infants below the age of one year are likely to suffer from  
[MP PMT 2001; CBSE PMT 2009; J & K CET 2010]  
(a) Marasmus (b) Rickets  
(c) Kwashiorkor (d) Pellagra
2. Statements  
A. The element which is very important for the production of thyroxine is iodine  
B. Vitamin B<sub>6</sub> is otherwise known as niacin or nicotinic acid  
C. Fructose is a monosaccharide and is a hexose sugar  
D. Globulin is an example for a conjugated protein  
Of the above statements  
[Kerala PMT 2008]  
(a) A, B and C are correct but D is wrong  
(b) A and C are correct but B and D are wrong  
(c) A and B are correct but C and D are wrong  
(d) A is correct while B, C and D are wrong  
(e) A, C and D are correct but B is wrong
3. The number of essential amino acids in adult human is [Odisha JEE 2009]  
(a) Nine (b) Eight  
(c) Four (d) Seven
4. Which one of the following statements is not correct [CBSE PMT 2014]  
(a) Retinal is a derivative of vitamin C  
(b) Rhodopsin is the purplish red protein present in rods only  
(c) Retinal is the light absorbing portion of visual photopigments  
(d) In retina the rods have the photopigment rhodopsin while cones have three different photopigments
5. Inadequate protein intake leads to kwashiorkor. The subsequent edema is most closely related to inadequate synthesis of which protein [DUMET 2009]  
(a) Gamma globulin (b) Glucagon  
(c) Insulin (d) Albumin
6. Hypochromic microcytic anaemia and leucopenia are caused by the deficiency of ..... respectively [EAMCET 2009]  
(a) Pyridoxine and riboflavin (b) Pyridoxine and folacin  
(c) Biotin and folacin (d) Biotin and cyanocobalamin
7. Liver necrosis and muscular dystrophy are caused by the lack of this trace element [AMU (Med.) 2009]  
(a) Arsenic (b) Molybdenum  
(c) Zinc (d) Selenium
8. This trace element is needed for insulin to exert its maximal effect in glucose uptake [AMU (Med.) 2010]  
(a) Vanadium (b) Chromium  
(c) Molybdenum (d) Selenium
9. Which of the following is a reducing sugar [CBSE PMT 2002; AFMC 2012]  
(a) Sucrose (b) Galactose  
(c) Gluconic acid (d)  $\beta$  - methyl galactoside
10. What is the common between amino acids, fatty acids and glycerol  
(a) These are all rich source of calories  
(b) These are the builders of protoplasm  
(c) These are the end products of digestion of two categories of food constituents  
(d) These can be stored in the form of fat
11. The smallest structural units of proteins are called [CPMT 1993; RPMT 1999]  
(a) Amino acids (b) Peptides  
(c) Proteoses (d) Peptones
12. In human per cent of body weight of carbohydrates, lipids and proteins respectively is [AMU (Med.) 2009]  
(a) 1, 15, 17 (b) 15, 17, 7  
(c) 7, 17, 15 (d) 17, 15, 7

13. During prolonged fasting [AFMC 1994; CBSE PMT 2003; CPMT 2005]  
 (a) The first to be used up are carbohydrates, next fat is withdrawn and proteins are metabolised at the last  
 (b) The first to be used up are the fats, next carbohydrates are withdrawn from stored glycogen in the liver and muscles and proteins are withdrawn at the last  
 (c) First lipids are used up, then proteins and finally carbohydrate  
 (d) None of these
14. To get sufficient carbohydrates one should take [CBSE PMT 2002]  
 (a) Meat (b) Rice  
 (c) Carrots (d) Ground nuts
15. Glucose and amino acids are absorbed in the intestine by [NCERT; JIPMER 2002]  
 (a) Active transport (b) Passive transport  
 (c) Selective absorption (d) Osmosis
16. Milk protein is [Manipal 1995]  
 (a) Rennin (b) Casein  
 (c) Galactose (d) Glycine
17. Unsaturated fatty acids have [Kerala CET 2002]  
 (a) Palmitic acid  
 (b) Stearic acid  
 (c) Oleic acid  
 (d) One or more double bonds
18. Which one of the following set is a polysaccharide group [CBSE PMT 1996; BHU 1999]  
 (a) Glucose, fructose, lactose  
 (b) Starch, glycogen, cellulose  
 (c) Sucrose, maltose, glucose  
 (d) Galactose, starch, sucrose
19. Lactose is composed of [CBSE PMT 1998; BHU 2000; DPMT 2006; WB JEE 2011]  
 (a) Glucose + fructose (b) Glucose + glucose  
 (c) Glucose + galactose (d) Fructose + galactose
20. The anhydro bond of proteins are called [Pb. PMT 2000]  
 (a) Glycosidic (b) Peptide  
 (c) Ester (d) Diester
21. Role of carbohydrates is to function as [NCERT; RPMT 1999]  
 (a) Catalyst (b) Source of energy  
 (c) Enzyme (d) Building material
22. Digestion of protein takes place in [NCERT; MP PMT 1996]  
 (a) Duodenum and stomach  
 (b) Stomach and oesophagus  
 (c) Small and large intestine  
 (d) Intestine and rectum
23. Amino acids not synthesized in the body are called [MP PMT 1996]  
 (a) Non-essential (b) Active  
 (c) Essential (d) Inactive
24. Essential : non-essential amino acid is [AMU (Med.) 2010]  
 (a) Lysine : leucine (b) Methionine : threonine  
 (c) Valine : tyrosine (d) Alanine : cystine
25. Most abundant mineral of animal body is [WB JEE 2010]  
 (a) Iron (b) Sodium  
 (c) Potassium (d) Calcium
26. Which element is the cause of itai itai disease [WB JEE 2009]  
 (a) Hg (b) Pb  
 (c) Cd (d) As
27. Which of the following is not a vitamin deficiency disease [CPMT 2010]  
 (a) Addison's disease (b) Goitre  
 (c) Keratomalacia (d) Xerophthalmia
28. Choose the correct non-protein amino acid [WB JEE 2009]  
 (a) Hydroxyproline (b) Hydroxylysine  
 (c) Cystine (d)  $\gamma$  amino butyric acid
29. Thiamine ( $B_1$ ) deficiency results in [AIIMS 2009, 13]  
 (a) Wernicke's syndromes (b) Korsakoff's syndromes  
 (c) Osteonecrosis (d) Tunnel vision
30. Vitamin D is synthesised by one of the following with the help of sunlight [AIIMS 1992; RPMT 1999; WB JEE 2010]  
 (a) Skin (b) Gall bladder  
 (c) Liver (d) Pancreas
31. Water soluble vitamins are [AFMC 2001; Kerala PMT 2007]  
 (a) Vitamin A, B and C (b) Vitamin B and C  
 (c) Vitamins C and D (d) None of these
32. Which of the following elements is a constituent of biotin [NEET (Karnataka) 2013]  
 (a) Magnesium (b) Calcium  
 (c) Phosphorus (d) Sulphur
33. Which of the following are required in minimum amount by human [DPMT 2006; AIIMS 2011]  
 (a) Iron, iodine, carbon, manganese, copper,  $O_2$   
 (b) Iron, iodine, manganese, copper, zinc, fluorine  
 (c) Iron, iodine, manganese, zinc, hydrogen  
 (d) Nitrogen, oxygen, zinc, fluorine
34. Which is not used up in human body [DPMT 2006]  
 (a) Calcium (b) Phosphorus  
 (c) Zinc (d) Barium
35. Simple storage protein that coagulates upon heating but remains soluble in dilute salt solution is correctly exemplified by [Kerala PMT 2004; WB JEE 2012]  
 (a) Globulin (b) Albumin  
 (c) Histone (d) Collagen
36. Fat soluble vitamins are  
 (a) Vitamin A, B and C (b) Vitamin A, B and D  
 (c) Vitamin A, D, E and K (d) Vitamin C and D
37. Vitamin C is [AFMC 2012]  
 (a) Ascorbic acid (b) Nicotinic acid  
 (c) Lipoic acid (d) Aspartic acid

38. A pregnant female delivers a baby who suffers from stunted growth, mental retardation, low intelligence quotient and abnormal skin. This is the result of [NEET 2013]  
(a) Over secretion of pars distalis  
(b) Deficiency of iodine in diet  
(c) Low secretion of growth hormone  
(d) Cancer of the thyroid gland
39. Main difference between brown fat and white fat is that the cells of brown fat  
(a) Are multicoloured (b) Have more mitochondria  
(c) Are polygonal in shape (d) All the above
40. Collagen is a [WB JEE 2009]  
(a) Phosphoprotein (b) Globulin  
(c) Derived protein (d) Scleroprotein
41. Higher animals cannot synthesize few fatty acids which are very essential for their growth and development. These fatty acids are typically [WB JEE 2012]  
(a) Saturated (b) Cycle  
(c) Unsaturated (d) Branched
42. Which vitamin gets destroyed by heating  
(a) Vitamin A (b) Vitamin E  
(c) Vitamin C (d) Vitamin K
43. Continued consumption of a diet rich in butter, red meat and eggs for a long period may lead to [AIIMS 2007]  
(a) Vitamin A toxicity  
(b) Kidney stones  
(c) Hypercholesterolemia  
(d) Urine laden with ketone bodies
44. Term "vitamin" was given by [CBSE PMT 1992]  
(a) James Lind (b) Sterling  
(c) Funk (d) J.C. Drummond
45. In vertebrate's body mainly the food is stored in the form of [BHU 2002]  
(a) Fat (b) Fat and glycogen  
(c) Glycogen (d) Proteins
46. Which of the following vitamins is water soluble as well as an anti-oxidant [BHU 2005; Bihar CECE 2006]  
(a) Vitamin B<sub>1</sub> (b) Vitamin A  
(c) Vitamin D (d) Vitamin C
47. Zinc is associated with [RPMT 2000]  
(a) Glycosylation (b) Immunization  
(c) Sulfation (d) Transcription
48. Vitamin K is required for [CPMT 2009; MP PMT 2013]  
(a) Converting prothrombin to thrombin  
(b) Synthesis of prothrombin  
(c) Calcium combination with prothrombin  
(d) All of the above
49. Iron is present in which one of the following [RPMT 2000]  
(a) Glycophorin (b) Nuclein  
(c) Lectin (d) Catalase
50. A balanced diet does not include [KCET 2011]  
(a) Carbohydrates and fats  
(b) Nucleic acids and enzymes  
(c) Proteins and vitamins  
(d) Minerals and salts
51. Vitamin D is synthesized in skin, by the action of sunlight on [CPMT 2000; BHU 2006]  
(a) Cholesterol (b) 7-hydroxy cholesterol  
(c) Cephalo-cholesterol (d) Ortho-phenoxy cholesterol
52. Which one is an amino acid [WB JEE 2011]  
(a) Pepsin (b) Proline  
(c) Cysteine (d) Renin
53. Cyanocobalamine is essential for the formation of [JIPMER 2002; AFMC 2012]  
(a) RBC (b) WBC  
(c) Lymph (d) Platelets
54. Salivary amylase is also known as [Manipal 2005]  
(a) Ptyalin (b) Gastrin  
(c) Glyoxylase (d) Pepsin
55. Beri-beri was discovered by  
(a) Funk (b) G.E. Foxan  
(c) Eijkman (d) Admiral Takaki
56. In a normal adult, ascending order of concentration of following molecules is [AIIMS 2012]  
(a) K>Na>Fe>Cu (b) Na>K>Cu>Fe  
(c) Fe>Na>K>Cu (d) Na>Fe>K>Cu
57. Megaloblastic anaemia of pregnancy is caused by the deficiency of  
(a) Vitamin B<sub>12</sub> (b) Vitamin B<sub>12</sub> and folic acid  
(c) Folic acid (d) Vitamin D
58. A non-essential amino acid is [AFMC 2002]  
(a) Lysine (b) Methionine  
(c) Alanine (d) Isoleucine
59. Which of the following is not an unsaturated fatty acid (essential) [CPMT 2009]  
(a) Oleic acid (b) Linoleic acid  
(c) Linolenic acid (d) Stearic acid
60. Fluorine helps in maintaining the  
(a) Dentine to deposit normally in teeth  
(b) Enamel deposition and prevents the dental carries  
(c) Erythropoiesis  
(d) Absorption of certain substances by the cell
61. Which one of the following is a fat-soluble vitamin and its related deficiency disease [CBSE PMT 2007]  
(a) Ascorbic acid - Scurvy  
(b) Retinol - Xerophthalmia  
(c) Cobalamine - Beri-beri  
(d) Calciferol - Pellagra
62. Cod and shark liver oil is a source of [Kerala PMT 2007]  
(a) Energetic nutrients  
(b) Constructive nutrients  
(c) Energetic and constructive nutrients  
(d) Protective nutrients  
(e) Protective and constructive nutrients
63. Certain vitamin B acts as [MP PMT 2002]  
(a) Enzymes (b) Coenzymes  
(c) Digestive enzymes (d) Hormones

64. Which one of the following vitamins is manufactured in human liver [BHU 2012]  
 (a) Vitamin A (b) Vitamin D  
 (c) Vitamin C (d) Vitamin K
65. Deficiency of it, causes loss of appetite, mental confusion, fatigue and muscle depreciation [GUJCET 2007]  
 (a) Vitamin - K (b) Vitamin - C  
 (c) Thiamine (d) Riboflavin
66. The following are needed for blood-clotting in mammals [MP PMT 1994, 97, 2001, 02; HPMT 2005; BHU 2006; VITEEE 2006; DPMT 2007; Kerala PMT 2009]  
 (a)  $Ca^{++}$  and Vitamin E (b)  $Ca^{++}$  and Vitamin K  
 (c)  $Ca^{++}$  and Vitamin A (d)  $K^+$  and Vitamin K
67. Which of the following is mismatched [CBSE PMT 1998, 99]  
 (a) Vitamin K – Beri-beri (b) Vitamin C – Scurvy  
 (c) Vitamin A – Xerophthalmia (d) Vitamin D – Rickets
68. In beri-beri [CBSE PMT 1993]  
 (a) The coagulation time increases  
 (b) Dermatitis in organs exposed to sun rays  
 (c) The depigmentation of skin and hair starts  
 (d) The affect over peripheral nervous system, gastro-intestinal tract and cardiovascular is pronounced
69. Examination of blood of a person suspected of having anaemia, shows large, immature, nucleated erythrocytes without haemoglobin. Supplementing his diet with which of the following is likely to alleviate his symptoms [AIEEE Pharmacy 2003; CBSE PMT 2006]  
 (a) Riboflavin (b) Iron compounds  
 (c) Thiamine (d) Folic acid and cobalamine
70. In mammals vitamin synthesised by the intestinal bacteria is [MP PMT 2006]  
 (a) Pantothenic acid (b)  $B_{12}$  (Cyanocobalamine)  
 (c) Biotin (d) Choline
71. Which of the following helps in synthesis of DNA and cell division [MP PMT 2001, 02; BHU 2002]  
 (a) Nicotinamide (b) Biotin  
 (c) Folic acid (d) Pantothenic acid
72. Which one is the most abundant protein in the animal world [CBSE PMT (Pre.) 2012]  
 (a) Trypsin (b) Haemoglobin  
 (c) Collagen (d) Insulin
73. Defective red blood corpuscles can be seen when there is a deficiency of [MP PMT 1993]  
 (a) Retinol (b) Vitamin K  
 (c) Vitamin  $B_2$  (Riboflavin) (d) Vitamin  $B_6$  (Pyridoxine)
74. General metabolism of the body will be affected due to the deficiency of [MP PMT 1993]  
 Or  
 One of the following minerals is responsible to regulate your heart beats  
 (a) Sodium (b) Calcium  
 (c) Iodine (d) Cobalt
75. Infertility is believed to be due to the lack of vitamin [AIIMS 1993; DPMT 1993; MP PMT 2012]  
 (a) A (b) B  
 (c) C (d) E
76. Animals consuming only plant materials are referred as [J & K CET 2005]  
 (a) Herbivores (b) Carnivores  
 (c) Omnivores (d) Insectivores
77. A person suffers from beri-beri, rickets and scurvy if he is not taking adequate amounts of [JIPMER 1993; MP PMT 1994, 95; Bihar MDAT 1995; CPMT 1995; BHU 1998, 99; Odisha JEE 2010; PET (Pharmacy) 2013]  
 (a) Vitamin  $B_{12}$ , A and C (b) Vitamin  $B_1$ , D and C  
 (c) Vitamin A, B and E (d) Vitamin  $B_6$ , and K
78. Riboflavin ( $B_2$  or G) is concerned with [CMC Vellore 1993; MP PMT 2012]  
 (a) Maintenance of epithelial cells of skin  
 (b) Iron porphyrin proteins  
 (c) Metal containing pigments  
 (d) Oxidation process and intermediate metabolism
79. A nutrient not required / has no function in plants except in Fabaceae, but essential nutrient of animals whose deficiency makes a person anemic as it is an integral part of vitamin B-12, and this nutrient is [Kerala CET 2003; MP PMT 2013]  
 (a) Iron (b) Calcium  
 (c) Cobalt (d) Cadmium
80. Rickets in children and osteomalacia in adults is caused by the deficiency of [NCERT; MP PMT 1996, 99, 2000, 03, 10; BHU 1999; CPMT 2001; CBSE PMT 2001; Kerala CET 2002; DUMET 2009; WB JEE 2009, 11]  
 Or  
 Weakening of limb bones may be due to deficiency of [MP PMT 1993]  
 (a) Vitamin A (b) Vitamin B  
 (c) Vitamin C (d) Vitamin D (calciferol)
81. Which one of the following is the best source for vitamin A (Antixerophthalmic) [AFMC 1996, 99; AIEEE Pharmacy 2003]  
 (a) Apples (b) Carrots  
 (c) Honey (d) Peanuts
82. Angiotensinogen is a protein produced and secreted by [CBSE PMT 2006]  
 (a) Liver cells  
 (b) Juxtaglomerular (JG) cells  
 (c) Macula densa cells  
 (d) Endothelial cells (cells lining the blood vessels)



83. Which one of the following is dominant intracellular cation [RPMT 2000]  
(a) Potassium (b) Chloride  
(c) Phosphate (d) Calcium
84. Vitamin  $B_{12}$  is available to ruminants by [DPMT 2006]  
(a) Plants  
(b) Micro-organisms in caecum  
(c) Animals  
(d) All of the above
85. A vitamin which is generally excreted in human urine is  
Or  
Earliest known vitamin is  
(a) C (b) K  
(c) A (d) D
86. The richest sources of vitamin  $B_{12}$  are [CBSE PMT 2004]  
(a) Rice and hen's egg  
(b) Carrot and chicken's breast  
(c) Goat's liver and Spirulina  
(d) Chocolate and green gram
87. To which of the following family do folic acid and pantothenic acid belong [CBSE PMT 1998, 99]  
(a) Vitamin K (b) Vitamin A  
(c) Vitamin C (d) Vitamin B complex
88. Which of the following is the correct match [KCET 1994; CBSE PMT 2001]  
(a) Vitamin A—calciferol (b) Vitamin E—tocopherol  
(c) Vitamin D—thiamine (d) Vitamin K—ascorbic acid
89. Pellagra is caused due to the deficiency of [CBSE PMT 1994, 96; MP PMT 1998, 2011; BHU 2000, 01, 03; DPMT 2003; AMU (Med.) 2006; WB JEE 2009; DUMET 2009]  
(a) Thiamine  
(b) Ascorbic acid  
(c) Niacin (Nicotinic Acid) ( $B_5$ )  
(d) Calciferol
90. One of the factors required for the maturation of erythrocytes is [CBSE PMT 1998; AFMC 2000]  
(a) Vitamin D (b) Vitamin A  
(c) Vitamin  $B_{12}$  (d) Vitamin C
91. Which is the best source for vitamin  $B_1$   
(a) Cod liver oil (b) Egg  
(c) Whole wheat bread (d) Curd
92. Xerophthalmia in children and nyctalopia (Night blindness) in adults is caused by the deficiency of vitamin [CBSE PMT 1992; MP PMT 1999, 2002; MH CET 2001; J & K CET 2002]  
(a) A (b) D  
(c) E (d) K
93. Which one of the following is very rich in magnesium [JIPMER 2002]  
(a) Meat (b) Egg  
(c) Soybean (d) Milk
94. Which one of the following pairs is **not** correctly matched [CBSE PMT 2004]  
(a) Vitamin  $B_1$  — Beri-beri  
(b) Vitamin  $B_5$  — Pellagra  
(c) Vitamin  $B_{12}$  — Pernicious anaemia  
(d) Vitamin  $B_6$  — Loss of appetite
95. Which one is correctly matched [Kerala PMT 2006]  
(a) Vitamin E — Thiamine (b) Vitamin D — Riboflavin  
(c) Vitamin  $B_1$  — Tocopherol (d) Vitamin A — Calciferol  
(e) Vitamin  $B_{12}$  — Cyanocobalamin
96. Which of the following is a fat soluble vitamin [MP PMT 2003]  
(a) Thiamine (b) Folic acid  
(c) Ascorbic acid (d) Tocopherol
97. Excessive intake of vitamin D leads to bone reabsorption and  
(a) Beri-beri (b) Hypercalcemia  
(c) Hyperkeratosis (d) Keratomalacia
98. Vitamin  $B_{12}$  is helpful  
(a) In the absorption of fats  
(b) To stimulate the liver  
(c) To stimulate the bone marrow  
(d) To increase life span of RBC
99. Starch is converted to maltose by the action of [CPMT 1999; JIPMER 2001]  
(a) Invertase (b) Amylase  
(c) Sucrase (d) Maltase
100. Recently discovered vitamin having anti-cancer properties is  
(a) Vitamin  $B_5$  (b) Vitamin  $B_{15}$   
(c) Vitamin  $B_{17}$  (d) Vitamin Q
101. How many of the twenty amino acids are essential amino acids for children [HP PMT 2005; Kerala PMT 2006]  
(a) 6 (b) 8  
(c) 10 (d) 7  
(e) 11
102. The vitamin nicotinamide can be synthesized in our body from [AIIMS 2002]  
(a) Tyrosine (b) Valine  
(c) Tryptophan (d) Phenyl alanine
103. Rhodopsin is synthesised with the help of [MP PMT 2000]  
(a) Vitamin A (b) Vitamin  $B_{12}$   
(c) Vitamin D (d) Vitamin  $B_6$
104. For normal absorption and deposition of calcium and phosphate the vitamin that is very necessary [MP PMT 1998; AIEEE Pharmacy 2003]  
Or  
Calcium deficiency in the body occurs in the absence of [CBSE PMT 1994]  
(a)  $B_1$  (b)  $B_2$   
(c) A (d) D
105. Nutrition involving engulfment of the whole or part of a plant or an animal in solid or in liquid state is known [J & K CET 2005; Kerala PMT 2009]  
(a) Holozoic (b) Saprophytic  
(c) Parasitic (d) Symbiotic

106. Match the following nutrition/vitamin deficiencies in column I with causes/deficiencies in column II and choose the correct option from the answer key

	Column I		Column II
(a)	Kwashiorkor	(p)	Iron
(b)	General Anaemia	(q)	Menadione
(c)	Dermatitis	(r)	Protein
(d)	Marasmus	(s)	Pyridoxin
(e)	Bleeding	(t)	Biotin

[Kerala CET 2005]

- (a) (a) – (p), (b) – (t), (c) – (q), (d) – (r), (e) – (s)  
 (b) (a) – (t), (b) – (q), (c) – (r), (d) – (s), (e) – (p)  
 (c) (a) – (q), (b) – (r), (c) – (s), (d) – (p), (e) – (t)  
 (d) (a) – (r), (b) – (p), (c) – (t), (d) – (s), (e) – (q)  
 (e) (a) – (r), (b) – (s), (c) – (p), (d) – (t), (e) – (q)
107. Iodine test used to detect [DPMT 2003]  
 (a) Protein (b) Fat  
 (c) Carbohydrate (d) Chitin
108. Which one of the following is antioxidant vitamin [DPMT 2003; BHU 2003]  
 (a) Vitamin C, E, A (b) Vitamin B<sub>1</sub>, B<sub>4</sub>  
 (c) Vitamin A, D, E (d) Vitamin B<sub>3</sub>, B<sub>5</sub>
109. Vitamin-C is mainly helpful in [MP PMT 2006]  
 (a) Growth of bones  
 (b) Formation of connective tissue  
 (c) Treatment of anaemia  
 (d) Formation of visual pigment
110. Continuous bleeding from an injured part of body is due to deficiency of [CBSE PMT 2002; MP PMT 2003]  
 (a) Vitamin A (b) Vitamin B  
 (c) Vitamin K (d) Vitamin E
111. Which group of three of the following five statement (1-5) contain is all three correct statements regarding beri-beri  
 1. A crippling disease prevalent among the native population of sub-Saharan Africa  
 2. A deficiency disease caused by lack of thiamine (vitamin B<sub>1</sub>)  
 3. A nutritional disorder in infants and young children when the diet is persistently deficient in essential protein  
 4. Occurs in those countries where the staple diet is polished rice  
 5. The symptoms are pain from neuritis, paralysis, muscle wasting, progressive oedema mental deterioration and finally heart failure. [CBSE PMT 2005]  
 (a) 2, 4 and 5 (b) 1, 2 and 4  
 (c) 1, 3 and 5 (d) 2, 3 and 5
112. 'Burning feet syndrome' is due to deficiency of  
 (a) Vitamin D (b) Vitamin A  
 (c) Vitamin B<sub>3</sub> (d) Vitamin B<sub>5</sub>
113. A patient of diabetes mellitus excretes glucose in urine even when he is kept in a carbohydrate free diet. It is because [Odisha JEE 2005]  
 (a) Fats are catabolised to form glucose  
 (b) Amino acids are catabolised in liver  
 (c) Amino acids are discharged in blood stream from liver  
 (d) Glycogen from muscles is released in blood stream.

114. The disease due to inflammation of vermiform appendix of digestive system is known as [CBSE PMT 1993]

(a) Amoebic dysentery (b) Intestinal cancer  
 (c) Appendicitis (d) None of the above

115. Which of the following is related with vitamin B<sub>2</sub> [AFMC 1997]

Or

Riboflavin is essential in our diet, as it is required for the synthesis of

(a) FMN / FAD (b) NAD  
 (c) NADH (d) NADH<sub>2</sub>

116. The method of intake of food in case of ciliate *Paramecium*  
 (a) Holozoic (b) Saprozoic  
 (c) Saprophytic (d) Parasitic
117. Which one of the following is a matching pair of a certain body feature and its value/count in a normal human adult [AIIMS 2003]  
 (a) Urea 5-10 mg/100 ml of blood  
 (b) Blood sugar 80-100 mg/100 ml  
 (c) Total blood volume 3-4 litres  
 (d) ESR in Wintrobe method 9-15 mm per hour in males and 20-34 mm per hour in females
118. Average kilocalorie of energy needed by woman is [NCERT; Odisha JEE 2005]  
 (a) Less than man (b) More than man  
 (c) Equal to man (d) Cannot be predicted
119. An average man needs approximately [NCERT; CBSE PMT 1999; MP PMT 2004]  
 (a) 2900 K cal. energy/day (b) 500 K cal. energy/day  
 (c) 1000 K cal. energy/day (d) 2000 K cal. energy/day
120. The people dependent exclusively on maize diet, are more likely to suffer from [AIEEE Pharmacy 2003]  
 (a) Rickets (b) Pellagra  
 (c) Beri-beri (d) Dysentery
121. Vasco de Gama (1498) sailed to explore India with 180 companions but most of them died due to  
 (a) Rickets (b) Pellagra  
 (c) Scurvy (d) Xerophthalmia
122. Anti-infection vitamin is  
 (a) B<sub>12</sub> (b) A  
 (c) D (d) K
123. Chemical formula of 'Retinol-1' is  
 (a) C<sub>6</sub>H<sub>5</sub>NO<sub>2</sub> (b) C<sub>3</sub>H<sub>10</sub>O<sub>3</sub>N  
 (c) C<sub>20</sub>H<sub>30</sub>O (d) C<sub>28</sub>H<sub>44</sub>O
124. Vitamin essential for formation of collagen is  
 (a) A (b) E  
 (c) B<sub>12</sub> (d) C
125. Which one of the following is the correct matching of a vitamin, its nature and its deficiency disease [CBSE PMT 2004; BCECE 2005]  
 (a) Vitamin A – Fat-soluble – Beri-beri  
 (b) Vitamin K – water-soluble – Pellagra  
 (c) Vitamin A – Fat-soluble – Night blindness  
 (d) Vitamin K – Fat-soluble – Beri-beri

126. Vitamin *E* is also known as  
[MP PMT 2002; Kerala CET 2003]  
(a) Decalcifying vitamin  
(b) Antisterility vitamin  
(c) Prothrombin vitamin  
(d) Antihaemophilic vitamin
127. Vitamin A was discovered by  
(a) McCollum and Davis (b) Funk  
(c) Hopkin (d) Eijkmann
128. Organisms, which obtain energy by oxidation of reduced inorganic compounds, are  
[CBSE PMT 2002]  
(a) Phototrophs (b) Saprozoic  
(c) Copro-heterotrophs (d) Chemo-autotrophs
129. Which vitamin is destroyed by ultraviolet rays  
(a) A (b) D  
(c) E (d) K
130. *E. coli* in human colon behave as  
[AFMC 2002]  
(a) Parasite (b) Commensal  
(c) Saprophyte (d) Mutualism
131. Vitamin M is  
(a) Nicotinic acid (b) Pantothenic acid  
(c) Folic acid (d) Ascorbic acid
132. The vitamin isolated from egg yolk by Kogl and Tonnin in 1943 was  
(a) Vitamin K (b) Vitamin M  
(c) Vitamin H (d) Vitamin B<sub>9</sub>
133. The vitamin which helps in carbohydrate metabolism during glycolysis and TCA cycle is  
(a) Riboflavin (b) Thiamine  
(c) Folic acid (d) Pantothenic acid
134. Which one of the following pairs is not correctly matched  
[CBSE PMT 2003]  
(a) Vitamin B<sub>6</sub> – Beri-beri  
(b) Vitamin C – Scurvy  
(c) Vitamin B<sub>5</sub> – Pellagra  
(d) Vitamin B<sub>12</sub> – Pernicious anaemia
135. Which set includes neurotic vitamins  
(a) Vitamin B<sub>12</sub>, B<sub>5</sub>, B<sub>2</sub> (b) Vitamin B<sub>2</sub>, B<sub>6</sub>, B<sub>12</sub>  
(c) Vitamin A, D, E (d) Vitamin B<sub>6</sub>, B<sub>12</sub>, K
136. Which one of the following vitamins can be synthesized by bacteria inside the gut  
[CBSE PMT 1997]  
(a) B<sub>1</sub> (b) A  
(c) D (d) K
137. Cow's milk is slightly yellowish in colour due to the presence of  
(a) Carotene (b) Riboflavin  
(c) Xanthophyll (d) Xanthophyll and carotene
138. The water soluble materials pass through the proteins called  
[Kerala CET 2003]  
(a) Glycoprotein (b) Glycocalyx  
(c) Extrinsic proteins (d) Channel proteins
139. Which combination is incorrect  
[CPMT 1994]  
(a) Niacine – Pellagra  
(b) Thiamine – Beri – beri  
(c) Vitamin K – Sterility  
(d) Vitamin D – Rickets
140. Vitamins, we must consume daily are  
[AFMC 1995; CBSE PMT 2000]  
(a) Fat soluble (b) Water soluble  
(c) Both (a) and (b) (d) None of these
141. Besides having C, H, O which of the following also contains N, S, P etc.  
[AFMC 1995]  
(a) Protein (b) Fat  
(c) Carbohydrate (d) Vitamin
142. Which of the following does not belong to vitamin B group  
[MP PMT 2002]  
(a) Riboflavin (b) Nicotin  
(c) Cyanocobalamine (d) Tocopherol
143. Milk sugar is  
[Bihar MDAT 1995; KCET 2010]  
(a) Sucrose (b) Galactose  
(c) Lactose (d) Glucose  
(e) Fructose
144. Which of the following is not a source of vitamin A  
[CPMT 2002; RPMT 2005, 06]  
(a) Carrot (b) Mango  
(c) Apple (d) Yeast
145. What does the doctor advise to the patients suffering from high blood cholesterol  
[CBSE PMT 1996]  
(a) Red mutton with fat layer  
(b) Vegetable and margerin  
(c) Vegetable oil such as ground-nut oil  
(d) Pure deshi ghee or butter
146. Deficiency of copper causes  
[MP PMT 1996]  
(a) Pellagra  
(b) Anaemia and damage to CNS  
(c) Influenza  
(d) Xerophthalmia
147. The main cause of anaemia (Hypochromic or macrocytic) is  
[MP PMT 1996, 99, 2006; AFMC 2006]  
(a) Deficiency of Ca  
(b) Deficiency of Fe  
(c) Deficiency of Na  
(d) Deficiency of Mg
148. Mode of nutrition in Amoeba is  
[HPMT 1993; MP PMT 2001]  
(a) Saprozoic (b) Holophytic  
(c) Coprozic (d) Holozoic
149. Balanced diet should have approximately  
[NCERT; AFMC 1994; CBSE PMT 2000]  
(a) 1/5 protein, 3/5 fat and 1/5 carbohydrate  
(b) 3/5 protein, 1/5 fat and 1/5 carbohydrate  
(c) 1/5 protein, 1/5 fat and 3/5 carbohydrate  
(d) 1/2 protein, 1/4 fat and 3/5 carbohydrate
150. Holophytic nutrition is found in  
[MP PMT 2000]  
(a) Amoeba (b) Giardia  
(c) Entamoeba (d) Euglena
151. Fish-liver oils contain large amounts of  
(a) Vitamin K  
(b) Vitamin E  
(c) Vitamins A and D  
(d) Vitamins B<sub>2</sub> and C

# NCERT

## Exemplar Questions

- Select what is not true of intestinal villi among followings [NCERT]
  - They possess microvilli
  - They increase the surface area
  - They are supplied with capillaries and the lacteal vessels
  - They only participate in digestion of fats
- Hepato-pancreatic duct opens into the duodenum and carries [NCERT]
  - Bile
  - Pancreatic juice
  - Both bile and pancreatic juice
  - Saliva
- One of the following is not a common disorder associated with digestive system [NCERT]
 

(a) Tetanus	(b) Diarrhoea
(c) Jaundice	(d) Dysentery
- A gland not associated with the alimentary canal is [NCERT]
 

(a) Pancreas	(b) Adrenal
(c) Liver	(d) Salivary glands
- Match the two columns and select the correct among options given
 

Column I	Column II
A. Biomacromolecules of food	i. Alimentary canal and associated gland
B. Human digestive system	ii. Embedded in jawbones
C. Stomach	iii. Outer wall of visceral organs
D. Thecodont	iv. Converted into simple substances
E. Serosa	v. J-shaped bag like structure

Options [NCERT]

(a) A-ii, B-i, C-v, D-iii, E-iv
(b) A-iv, B-i, C-v, D-ii, E-iii
(c) A-i, B-ii, C-iii, D-iv, E-v
(d) A-i, B-iii, C-ii, D-iv, E-v
- Match the two columns and select the right one among options given
 

Column I	Column II
A. Duodenum	i. A cartilaginous flap
B. Epiglottis	ii. Small blind sac
C. Glottis	iii. 'U' shaped structure emerging from the stomach
D. Caecum	iv. Opening of wind pipe

Options [NCERT]

(a) A-i, B-ii, C-iii, D-iv
(b) A-iv, B-iii, C-ii, D-i
(c) A-iii, B-i, C-iv, D-ii
(d) A-ii, B-iv, C-i, D-iii

- Match the enzyme with their respective substrate and choose the right one among options given
 

A. Lipase	i. Dipeptides
B. Nuclease	ii. Fats
C. Carboxypeptidase	iii. Nucleic acids
D. Dipeptidases	iv. Proteins, peptones and proteoses

Options [NCERT]

(a) A-ii, B-iii, C-i, D-iv
(b) A-iii, B-iv, C-ii, D-i
(c) A-iii, B-i, C-iv, D-ii
(d) A-ii, B-iii, C-iv, D-i
- Liver is the largest gland and is associated with various functions, choose one which is not correct [NCERT]
  - Metabolism of carbohydrate
  - Digestion of fat
  - Formation of bile
  - Secretion of hormone called gastric
- Mark the right statement among the following [NCERT]
  - Trypsinogen is an inactive enzyme
  - Trypsinogen is secreted by intestinal mucosa
  - Enterokinase is secreted by pancreas
  - Bile contains trypsin



## Critical Thinking

### Objective Questions

- This is the common passage for bile and pancreatic juices [NCERT; AMU (Med.) 2010, 12]
 

(a) Ampulla of Vater	(b) Ductus Choledochus
(c) Duct of Wirsung	(d) Duct of Santorini
- Digestion in *Hydra* takes place within [Odisha JEE 2009]
 

(a) Pelvic cavity	(b) Abdominal cavity
(c) Pericardial cavity	(d) Gastrovascular cavity
- Which is the characteristic lining of stomach of mammals [MP PMT 1993]
 

(a) Paneth cells	(b) Deiter cells
(c) Oxyntic cells	(d) Kupffer cells
- Fatty acid and glycerol are first taken up from alimentary canal by [AFMC 1994]
 

(a) Villi	(b) Blood capillaries
(c) Hepatic portal vein	(d) Lymph vessels
- Erythropoiesis starts in [DUMET 2009; AIPMT (Cancelled) 2015]
 

(a) Kidney	(b) Liver
(c) Spleen	(d) Red bone marrow
- In rabbit the colour of bile juice is
  - Colourless due to the presence of sodium and potassium taurocholate
  - Green due to the accumulation of biliverdin
  - Red due to the accumulation of haemoglobin
  - Yellow due to the presence of bilirubin
- During absorption of carbohydrates in the blood the most rapidly transported monosaccharide is [BHU 2012]
 

(a) Glucose	(b) Galactose
(c) Fructose	(d) Sucrose

8. The wall of the stomach is protected against the action of HCl by [J & K CET 2010]

(a) Epidermal layer (b) Mesodermal layer  
(c) Mucous layer (d) Muscular layer

9. Column I contains names of the sphincter muscles of the alimentary canal and column II contains their locations. Match them properly and choose the correct answer

	Column I		Column II
A.	Sphincter of ani internus	1.	Opening of hepatopancreatic duct into duodenum
B.	Cardiac sphincter	2.	Between duodenum and posterior stomach
C.	Sphincter of Oddi	3.	Guarding the terminal part of alimentary canal
D.	Ileocaecal sphincter	4.	Between oesophagus and anterior stomach
E.	Pyloric sphincter	5.	Between small intestine and bowel

[NCERT; KCET 2011]

- (a) A-3, B-2, C-4, D-1, E-5  
(b) A-2, B-5, C-1, D-4, E-3  
(c) A-3, B-4, C-1, D-5, E-2  
(d) A-4, B-3, C-1, D-2, E-5

10. The pungent odour of faeces is due to presence of [MP PMT 1997]

(a) Indole (b) Skatole  
(c) Various gases (d) All the above

11. Maximum percentage of lipoprotein is present in [DPMT 2007]

(a) Chylomicron (b) HDL  
(c) VDL (d) VLDL

12. Where do certain symbiotic microorganisms normally occur in human body [NCERT; CBSE PMT (Main) 2012]

(a) Caecum  
(b) Oral lining and tongue surface  
(c) Vermiform appendix and rectum  
(d) Duodenum

13. For the enzyme action [BHU 1995]

(a) Value of  $K_m$  is unchange (b) Value of  $K_m$  is low  
(c) Value of  $K_m$  is constant (d) Value of  $K_m$  is high

14. Inhibition of gastric secretion is brought about by [CMC Vellore 1993; CBSE PMT 1994; MP PMT 2003; CPMT 2005]

Or

Which of these is not an enzyme of digestive system

(a) Cholecystokinin (b) Pancreozymin  
(c) Gastrin (d) Enterogastron

15. A principal gastrointestinal hormone is

(a) Prolactin (b) Choline esterase  
(c) Secretin (d) Acetyl

16. The activator of intestinal juice is [JIPMER 1993]

Or

Mechanical stimulation of villi by the food produces a hormone which is known as [RPMT 2005]

(a) Succus entericus (b) Secretin  
(c) Enterocrinin (d) Enterozymase

17. Anxiety and eating spicy food together in an otherwise normal human, may lead to

[NCERT; CBSE PMT (Pre.) 2012]

(a) Indigestion (b) Jaundice  
(c) Diarrhoea (d) Vomiting

18. Wisdom teeth in human is [CPMT 2002; RPMT 2005]

(a) 3<sup>rd</sup> molar & 4 in number (b) 3<sup>rd</sup> molar & 2 in number  
(c) 2<sup>nd</sup> molar & 4 in number (d) 2<sup>nd</sup> molar & 2 in number

19. In the stomach, gastric acid is secreted by the

[NEET (Phase-I) 2016]

(a) Gastrin secreting cells (b) Parietal cells  
(c) Peptic cells (d) Acidic cells

20. Which of the following can be called 'animal starch'

[AIIMS 1993]

(a) Hemicellulose (b) Glucose  
(c) Glycogen (d) Chitin

21. One of the following is needed for the conversion of trypsinogen into trypsin [NCERT; CBSE PMT 1995, 99; AFMC 1996; BHU 2000; Kerala PMT 2008]

Or

Trypsinogen is an inactive enzyme secreted by the pancreas. It is activated by [WB JEE 2016]

(a) HCl (b) Enterokinase  
(c) Lipase (d) Zymase

22. Lesion in ventromedial hypothalamus [MP PMT 2004]

(a) Increases hunger (b) Decreases hunger  
(c) Do not change hunger (d) Stop eating

23. Antihaemorrhagic vitamin is [BHU 2008]

(a) Vitamin A (b) Vitamin B  
(c) Vitamin C (d) Vitamin K

24. The mine workers are most likely to suffer from

(a) Beri-beri (b) Osteomalacia  
(c) Scurvy (d) Xerophthalmia

25. Write proper option by matching column I, II and III

Column I (Name)	Column II (Enzyme)	Column III (Function)
(i) Gastric Juice	(P) Chymo-trypsinogen	(A) Dipeptide convert into amino acid
(ii) Intestinal Juice	(Q) Ptyalin	(B) Proteoses convert into small polypeptides
(iii) Saliva	(R) Renin	(C) Casein convert into paracasein
(iv) Pancreatic juice	(S) Erepsin	(D) Conversion of starch into maltose

[GUJCET 2015]

- (a) (i - R - C) (ii - S - A) (iii - Q - B) (iv - P - D)  
(b) (i - R - C) (ii - S - A) (iii - Q - D) (iv - P - B)  
(c) (i - S - D) (ii - R - C) (iii - P - B) (iv - Q - A)  
(d) (i - Q - A) (ii - P - C) (iii - R - B) (iv - S - D)

26. Wound healing is enhanced by a vitamin [MP PMT 2002]

(a) A (b) C  
(c) D (d) E

27. Which of the following pair is characterised by swollen lips, thick pigmented skin of hands and legs and irritability

[CPMT 2004]

(a) Iodine - Goitre  
(b) Protein - Kwashiorkor  
(c) Thiamine - Beri-Beri  
(d) Nicotinamide - Pellagra

28. Select the mismatch between a vitamin and its deficiency disease, among the following [AIEEE Pharmacy 2004]  
 (a) Riboflavin-slow clotting of blood  
 (b) Niacin-damage to skin and lining of intestine  
 (c) Ascorbic acid-scurvy  
 (d) Thiamine-damage to nerves and heart.
29. The delicious food generally makes mouth watery. It is due to [J & K CET 2002]  
 (a) Hormonal response (b) Neural response  
 (c) Olfactory response (d) Optic response
30. A triglyceride molecule has or A typical fat molecule is made up of [Kerala CET 2003; NEET (Phase-I) 2016]  
 (a) Three fattyacids with one glycerol molecule  
 (b) Three fattyacids with two glycerol molecule  
 (c) Two fattyacids with two glycerol molecules  
 (d) One fattyacid with one glycerol molecule
31. Excessive stimulation of vagus nerve in humans may lead to [AIIMS 2003]  
 (a) Hoarse voice  
 (b) Peptic ulcers  
 (c) Efficient digestion of proteins  
 (d) Irregular contractions of diaphragm
32. Protein deficiency in children is called [KCET 1994; CBSE PMT 1998; BHU 2003; DPMT 2007; AFMC 2008; CPMT 2008]

Or

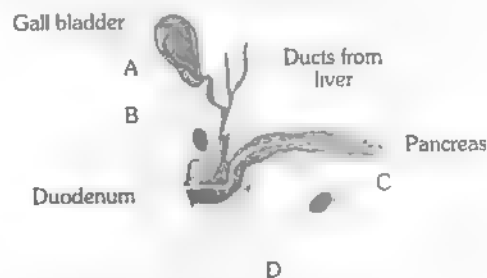
In Africa and South-east Asia, people like to have much bread and butter than pulses. They suffer

- (a) Obesity (b) Marasmus  
 (c) Diabetes (d) Kwashiorkor
33. The intestine is different from the stomach by the presence of [NCERT; AIIMS 1993]  
 (a) Digestive gland (b) Villi  
 (c) Sub-mucosa (d) Serosa
34. In the empty stomach, mucosal folds appear. They are called [MP PMT 2002]  
 (a) Fiveoles (b) Ancinura angularis  
 (c) Rugae (d) None
35. Which of the following controls the peristaltic movement of the intestine [BHU 2002]  
 (a) Sacral plexus (b) Brachial plexus  
 (c) Discoidal plexus (d) Auerbach's plexus
36. Secretin hormone is secreted by [CBSE PMT 2002]  
 (a) Liver (b) Pancreas  
 (c) Intestine (d) Brunner's glands
37. Consider the following statements  
 A. The anti pellagra vitamin is nicotinamide present in milk, yeast, meat and leafy vegetables  
 B. Crypts of Leiberkuhn are present in the liver  
 C. Steapsin is the pancreatic amylase [Kerala PMT 2007]  
 (a) A and B correct (b) B and C correct  
 (c) A and C incorrect (d) A and C correct  
 (e) B and C incorrect
38. Digestion process in humans is [BHU 2002]  
 (a) Extracellular (b) Intracellular  
 (c) Interacellular (d) Both (a) and (c)
39. Mumps are caused due to  
 (a) Excessive cold  
 (b) Viral infection in tonsils  
 (c) Viral infection of parotid salivary glands  
 (d) Viral infection of zygomatic glands

40. The folds of Kerkring are developed in  
 (a) Duodenum (b) Jejunum  
 (c) Ileum (d) Large intestine
41. Meckel's diverticulum is found in [JIPMER 2002]  
 (a) Ileum (b) Appendix  
 (c) Pylorus (d) Rectum
42. Which of the following carries glucose from digestive tract to liver [CBSE PMT 1999; Pb. PMT 2000; BHU 2001]  
 (a) Hepatic artery (b) Pulmonary vein  
 (c) Hepatic portal vein (d) Renal portal system
43. Which of the following sugars is absorbed from the small intestine by facilitated diffusion [CBSE PMT 2001]  
 (a) Fructose (b) Glucose  
 (c) Sucrose (d) Lactose
44. Mammals drink water and also obtain it from [MP PMT 2013]  
 (a) Break down of glycogen into glucose  
 (b) Secretion of saliva  
 (c) Conversion of oxyhaemoglobin to haemoglobin  
 (d) Oxidation of glucose
45. Select the correct match of the digested products in humans given in Column I with their absorption site and mechanism in Column II [NEET 2013]

	Column I	Column II
(a)	Cholesterol, maltose	Large intestine, active absorption
(b)	Glycine, glucose	Small intestine, active absorption
(c)	Fructose, Na <sup>+</sup>	Small intestine, passive absorption
(d)	Glycerol, fatty acids	Duodenum, move as chylomicrons

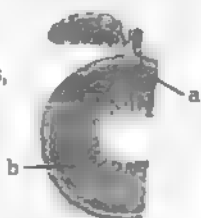
46. A healthy person eats the following diet-5gm raw sugar, 4 gm albumin, 10 gm pure buffalo ghee adulterated with 2gm vegetable ghee (hydrogenated vegetable oil) and 5 gm lignin. How many calories he is likely to get [NEET (Karnataka) 2013]  
 (a) 126 (b) 164  
 (c) 112 (d) 144
47. The given figure is a duct system of liver, gall bladder and pancreas. Identify the names of ducts from A to D [NCERT]



- (a) A - Cystic duct, B - Pancreatic duct, C - Bile duct, D - Hepato - pancreatic duct  
 (b) A - Cystic duct, B - Bile duct, C - Hepato - pancreatic duct, D - Pancreatic duct  
 (c) A - Bile duct, B - Cystic duct, C - Pancreatic duct, D - Hepato - pancreatic duct  
 (d) A - Cystic duct, B - Bile duct, C - Pancreatic duct, D - Hepato - pancreatic duct

48. Which option is correct for the region labelled as 'a' and 'b' in the given diagram of transverse section of gut

[GUJCET 2014]



- (a) a = Nerve,  
b = Circular muscle  
(b) a = Sub mucosal plexus of vessels,  
b = Mucosal gland  
(c) a = Villi,  
b = Mucosal gland  
(d) a = Longitudinal muscle,  
b = Muscularis mucosa

49. Pituitary gland is located in 'a', which is a 'b' and 'c' bone

[GUJCET 2014]

- (a) a = Sella turcica, b = Raised surface, c = Ethmoid  
(b) a = Reket's pouch, b = Depression, c = Nasal  
(c) a = Sella turcica, b = Depression, c = Sphenoid  
(d) a = Reket's pouch, b = Depression, c = Sphenoid

50. The enzyme that is not present in succus entericus is

[AIPMT 2015]

- (a) Nucleases (b) Nucleosidase  
(c) Lipase (d) Maltase

51. Good vision depends on adequate intake of carotene rich food

Select the best option from the following statements

- (A) Vitamin A derivatives are formed from carotene  
(B) The photopigments are embedded in the membrane discs of the inner segment  
(C) Retinal is a derivative of Vitamin A  
(D) Retinal is a light absorbing part of all the visual photopigments

Options

[NEET 2017]

- (a) (A) and (B) (b) (A), (C) and (D)  
(c) (A) and (C) (d) (B), (C) and (D)

## R Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

- (a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion  
(b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion  
(c) If the assertion is true but the reason is false  
(d) If both the assertion and reason are false  
(e) If the assertion is false but reason is true

1. Assertion : Blood sugar level falls rapidly after hepatectomy.  
Reason : The glycogen of the liver is the principal source of blood sugar. [KCET 2009]  
2. Assertion : Arachidic acid is an unsaturated fatty acid  
Reason : There are present one or more double bonds between carbon atoms in unsaturated fatty acids [AIIMS 2007]  
3. Assertion : Rumen of alimentary canal of ruminant animals harbour numerous bacteria and protozoa.  
Reason : Bacteria and protozoa help in the secretion of gastric juice in the rumen.

4. Assertion : Many tube like glands are present in the wall of small intestine.  
Reason : These glands secrete enzymes DNAse and RNAse into the intestinal juice.  
5. Assertion : Minerals are not biologically active substances.  
Reason : Some individuals suffer anaemia due to deficiency of copper. [AIIMS 2009]  
6. Assertion : Thick layers of muscles are present in the wall of alimentary canal  
Reason : These muscles help in the mixing of food materials with the enzymes coming from different glands in the alimentary canal. [AIIMS 2007, 10]  
7. Assertion : In alcoholic fermentation, the hexose molecule is converted into glucose and fructose.  
Reason : Alcoholic fermentation is anaerobic respiration brought about by enzyme zymase. [AIIMS 1996]  
8. Assertion : Insulin is secreted by  $\alpha$ -cells of islets of Langerhans of pancreas.  
Reason : Insulin promotes conversion of glucose to glycogen. [AIIMS 1996]  
9. Assertion : Carbohydrates are more suitable for the production of energy in the body than proteins and fats.  
Reason : Carbohydrates can be stored in the tissues as glycogen for use in the production of energy, whenever necessary.  
10. Assertion : The amino acid glycine comes under the category of nonessential amino acids.  
Reason : This is due to the fact that it can not be synthesised in the body. [AIIMS 2010]  
11. Assertion : Scurvy is caused by deficiency of vitamin.  
Reason : Deficiency of ascorbic acid causes scurvy. [AIIMS 2001]  
12. Assertion : The main part of carbohydrate digestion takes place in small intestine  
Reason : Here pancreatic amylase converts carbohydrates into lactose. [AIIMS 1995]  
13. Assertion : In alcoholic drink, the alcohol is converted into glucose in the liver.  
Reason : Liver cells are able to produce glucose from alcohol by back fermentation. [AIIMS 1996]  
14. Assertion : Adult human being is not perfect in digestion of milk.  
Reason : With age, man produces little or no lactase in the intestinal juice.  
15. Assertion : Trypsin helps in blood digestion of predator animals.  
Reason : Trypsin hydrolyses fibrinogen.  
16. Assertion : Volume and fluidity of intestinal contents have increased in a person.  
Reason : The person drank sea water.  
17. Assertion : Sea-faring fishermen sometimes eat raw fish  
Reason : They can be deficient of Vitamin B<sub>1</sub>. [AIIMS 2001]

## 806 Digestion and Absorption

18. Assertion : Starch is hydrolysed by ptyalin to maltose.  
Reason : Sucrase hydrolyses sucrose to lactose  
[AIIMS 2001]
19. Assertion : Cold blooded animals have no fat layer.  
Reason : Cold blooded animals use their fat for metabolic process during hibernation.  
[AIIMS 1997]
20. Assertion : Absorption of digested food mainly occurs in the stomach.  
Reason : Stomach produces the hormone gastrin and the intrinsic factor and it liquifies ingested food.  
[AIIMS 1996]

## Answers

### Digestive system

1	a	2	e	3	b	4	b	5	c
6	a	7	c	8	a	9	a	10	c
11	b	12	c	13	d	14	a	15	c
16	d	17	b	18	a	19	a	20	c
21	b	22	d	23	c	24	a	25	d
26	d	27	a	28	c	29	c	30	b
31	c	32	d	33	b	34	c	35	a
36	b	37	c	38	b	39	b	40	b
41	a	42	b	43	b	44	e	45	c
46	c	47	d	48	b	49	a	50	d
51	d	52	b	53	b	54	d	55	a
56	b	57	c	58	a	59	d	60	a
61	c	62	a						

### Digestive glands

1	d	2	d	3	a	4	b	5	a
6	b	7	b	8	c	9	b	10	b
11	d	12	c	13	a	14	d	15	b
16	b	17	c	18	a	19	b	20	c
21	a	22	a	23	c	24	a	25	b
26	a	27	b	28	a	29	c	30	c
31	b	32	b	33	b	34	d	35	c
36	c	37	b	38	b	39	a	40	d
41	b	42	b	43	b	44	a	45	a
46	d	47	c	48	c	49	b	50	b
51	a	52	d	53	b	54	a	55	c
56	d	57	a	58	d	59	c	60	b
61	d	62	c	63	b	64	b		

### Physiology of digestion

1	d	2	c	3	a	4	d	5	c
6	c	7	d	8	c	9	a	10	c
11	a	12	c	13	b	14	a	15	a
16	b	17	a	18	d	19	d	20	d
21	b	22	b	23	d	24	b	25	c
26	b	27	c	28	a	29	a	30	b
31	b	32	c	33	a	34	a	35	a
36	b	37	d	38	d	39	a	40	a
41	b	42	a	43	d	44	b	45	a
46	a	47	a	48	c	49	d	50	b
51	d	52	a	53	d	54	b	55	a
56	c	57	b	58	d	59	d		

### Gastro intestinal hormones/Digestive enzymes

1	a	2	d	3	d	4	c	5	c
6	d	7	c	8	d	9	a	10	c
11	d	12	a	13	a	14	a	15	c
16	a	17	d	18	d	19	b	20	c
21	b	22	c	23	a	24	c	25	d
26	c	27	a	28	d	29	a	30	c
31	a	32	b	33	d	34	d	35	d
36	c	37	a	38	a	39	a	40	c
41	c	42	b	43	c				

### Nutrition and Nutritional requirement

1	a	2	b	3	b	4	a	5	d
6	b	7	d	8	b	9	b	10	c
11	a	12	a	13	a	14	b	15	a
16	b	17	d	18	b	19	c	20	b
21	b	22	a	23	c	24	c	25	d
26	c	27	b	28	d	29	a	30	a
31	b	32	d	33	b	34	d	35	b
36	c	37	a	38	b	39	b	40	d
41	c	42	c	43	c	44	c	45	b
46	d	47	b	48	b	49	d	50	b
51	b	52	b	53	a	54	a	55	c
56	a	57	b	58	c	59	d	60	b
61	b	62	d	63	b	64	a	65	c
66	b	67	a	68	d	69	d	70	b
71	c	72	c	73	d	74	a	75	d
76	a	77	b	78	a	79	c	80	d
81	b	82	a	83	a	84	b	85	a



86	c	87	d	88	b	89	c	90	c
91	c	92	a	93	c	94	d	95	e
96	d	97	b	98	c	99	b	100	c
101	c	102	c	103	a	104	d	105	a
106	d	107	c	108	a	109	b	110	c
111	a	112	c	113	a	114	c	115	a
116	a	117	b	118	a	119	a	120	b
121	c	122	b	123	c	124	d	125	c
126	b	127	a	128	d	129	c	130	d
131	c	132	c	133	b	134	a	135	b
136	a	137	b	138	d	139	c	140	b
141	a	142	d	143	c	144	d	145	c
146	b	147	b	148	d	149	c	150	d
151	c								

### NCERT Exemplar Questions

1	d	2	c	3	a	4	b	5	b
6	c	7	d	8	d	9	a		

### Critical Thinking Questions

1	a	2	d	3	c	4	d	5	b
6	b	7	b	8	c	9	c	10	d
11	a	12	a	13	b	14	d	15	c
16	c	17	a	18	a	19	b	20	c
21	b	22	b	23	d	24	b	25	b
26	b	27	d	28	a	29	b	30	a
31	b	32	d	33	b	34	c	35	d
36	d	37	e	38	d	39	c	40	b
41	a	42	c	43	a	44	d	45	b
46	d	47	d	48	b	49	c	50	a
51	b								

### Assertion and Reason

1	a	2	d	3	c	4	c	5	d
6	a	7	e	8	e	9	b	10	c
11	a	12	c	13	d	14	a	15	a
16	a	17	a	18	d	19	b	20	e

## S Answers and Solutions

### Digestive system

- (a) The lower Jaw of man is formed by the fusion of dentary bone only.
- (e) Dental formula of Rabbit is  $\frac{2.0.3.3}{1.0.2.3} \times 2 = \frac{16}{12} = 28$
- (b) Upper canines are most developed in Walrus.

- (b) Crown of the teeth is covered by the hardest substance of the body called enamel.
- (c) Foliate papillae are present only on tongue of rabbit.
- (c) In frog teeth are pre maxillary, maxillary and vomerine
- (d) Tongue forms the floor of the oral cavity and it helps in the act of swallowing, help in mixing saliva with the food, help in speaking etc.
- (a) Dental formula for milk teeth is  $\frac{2102}{2102}$  so premolars are absent.
- (c) Taste buds for bitter taste are found on tongue at posterior part while anterior tip for sweetness and lateral sides are responsible for sour.
- (b) If a person suddenly starts coughing while swallowing food, it is due to improper movement of epiglottis. If the glottis is not properly closed some food can enter respiratory tract
- (a) In mammals, the digestion starts from mouth. Mouth contain 3-pair salivary gland which secretes saliva. Saliva contains a starch splitting enzyme ptyalin which acts on cooked starch changing them into a sugar maltose, isomaltose and limit dextrin.
- (c) The dental formula of Rabbit is  $\frac{2033}{1023} - \frac{8}{6} \times 2 = 28$ , so 28 teeth occur in rabbit, canines are absent and Diastema is present between incisor and premolar
- (b) Premolar and molar teeth with transverse ridges called lophos, so, premolar and molar are lophodont occurs in rabbit and elephant.
- (c) Upper incisor of an elephant is an enormously enlarged, called tusk teeth.
- (d) The third molar appear very late and are called wisdom teeth. From evolutionary point of view it is vestigial structure.
- (d) Teeth of frog are homodont, acrodont and polyphyodont. They are small, sharp and backwardly directed which are not meant for mastication but for preventing escape of prey
- (a) Dentine forming cells, the odontoblasts line the pulp cavity of teeth.
- (c) Lacteals are central lymph vessel found in villi of intestine. It is related to absorption of fats
- (c) The wall of alimentary canal is made up of four basic layers. First of all there is serosa which is a thin membranous covering around oesophagus. Then there is muscle layer-outer layer of longitudinal muscles and inner layer of circular muscles. Last there is submucosa which contains a few oesophageal glands. Then comes mucosa which have several layers of flattened cells.
- (b) Dental formula of human is  $\frac{2.1.2.3}{2.1.2.3} = \frac{8}{8} \times 2 = 32$ . It shows the number of incisor 2, canine 1, premolar 2 molar 3 in each half upper and half lower jaw with 32 teeth in buccal cavity.
- (c) Animals which eat their own faeces are called pseudo ruminants or coprophagus and phenomenon is known as pseudo rumination or coprophagy. e.g., Rabbit, Guinea pig
- (c) The muscular contraction in alimentary canal is known as peristalsis due to which the food passes from front to backward direction in the lumen of alimentary canal

35. (a) Its large broader anterior part is called cardiac stomach, while the short narrower posterior part the pyloric stomach. So fundic part is absent in Stomach of frog.
36. (b) The fundic part of stomach consist 2 type of cells, chief or zymogenic cell secretes pepsin and oxyntic or parietal cell secretes  $HCl$
38. (b) Inner lining of gut, stomach and liver is composed of simple columnar epithellium, single layer of non ciliated rectangular cells contains goblet cells, nuclei at basis of cell
39. (b) The mucosal lining of the oesophagus of mammals is made of squamous epithelium, several layers of cell deep layers, deep layers are cuboidal to columnar surface layers flat and scale like.
41. (a) Casein is a phosphoprotein found in milk. It is digested by rennin enzyme.
42. (b) The site of protein digestion is stomach where pepsin enzyme occur which changes protein to peptones + proteases.
43. (b) Stomach of ruminants is divided in 4 chamber, Rumen, Reticulum, omasum and abomasum. Some ruminants like camel and deer do not have omasum.
46. (c) In the wall of intestine, lymphatic tissue are present called peyer's patches. Peyer's patches are a group of lymph nodules that are most numerous in the ileum and produce lymphocyte.
50. (d) Peyer's patches are found in the ileum of mammals.
51. (d) Water is mostly absorbed in colon. Colon is a part of large intestine.
52. (b) The intestinal juice or succus entericus is secreted by crypts of lieberkuhn.
55. (a) Goblet cells are specialized unicellular cells that secrete mucus and form glands of the epithelium the stomach, intestine and part of the respiratory tract.
57. (c) Brunner's gland are found in submucosa of duodenum.
58. (a) Chief cells or pepsinogenic or zymogenic cells secretes pepsinogen and prorennin. These cells are situated in fundic part of stomach.
59. (d) Intestinal villi are mainly concerned with the absorption, the main function of intestinal villi is to provide large surface area for absorption.
60. (a) Crypt of lieberkuhn is a type of simple tubular glands in which secretory portion is straight and tubular
62. (a) Vermiform appendix is vestigeal organ of man which is found in alimentary canal.
8. (c) Pancreatic juice is also called as complete digestive juice. It contains trypsin, chymotrypsin, amylase, and lipase, which digest all types of food materials.
9. (b) Gastric juice of infants contains pepsinogen, lipase and rennin.
10. (b) Ptyalin is slightly acidic because its pH value is 6.8.
11. (d) Liver cell synthesiza vitamin A from carotene and store vitamins A, D and  $B_{12}$ .
12. (c) Argentaffin cells are generally located at the base of gastric glands and secrete serotonin.
15. (b) Pancreas is a mixed gland its exocrine part release enzyme and endocrine part release hormones so, pancreatic juice and hormones are secreted by different cell.
16. (b) Amylase is present in saliva it is slightly acidic nature because its pH value is 6.8.
18. (a) Intestinal juice is a clear yellow fluid with slightly alkaline nature pH of 7.6, contains water, mucus and enzymes.
19. (b) Intestinal juice or succus entericus is mainly secreted by crypts of lieberkuhn.
20. (c) Liver of rabbit is partly divided into 5 lobes; three lobes on left side are a small spigelian, left lateral and left central, while two lobes on the right side are caudate and right central or cystic.
24. (a) Sub maxillary and sub lingual glands are salivary gland secretes saliva, which participates in digestion of starch.
25. (b) Human beings have 3 pairs of salivary glands parotid, submandibular and sublingual.
26. (a) Ptyalin is an enzyme of salivary juice.
27. (b) Ptyalin (salivary amylase) and pancreatic amylase are the starch splitting enzyme released by salivary gland and pancreas.
28. (a) A lubricant mucin in saliva is made up of glycoprotein.
29. (c) Liver detoxifies and neutralises harmful substances.
30. (c) The trypsin enzyme is present in pancreatic juice which is secreted by pancreas.
31. (b) Bilirubin and biliverdin are bile pigments and are present in the bile juice
33. (b) By cystic duct bile juice passes into gall-bladder from liver.
34. (d) Infra orbital salivary gland is absent in man while in other mammals such as rabbit it is found.
35. (c) Bile juice contains bile salts and bile pigments.
36. (c) Gastric juices have pH 2-3.7.
37. (b) The bacteria are found in the colon which infact are the main source of vitamin- $B_{12}$  as vitamin- $B_{12}$  is not found in plants. Few micro-organisms of the rumen of stomach of ruminant mammals also synthesize large quantity of vitamin- $B_{12}$ .
38. (b) In human body glycogen is stored in liver and muscles both total 400 gm. glycogen stored, 100 gm. in Liver and 300 gm. in muscles
39. (a) Gastric juice is secreted by gastric glands. It consist pepsin, rennin, lipase.
40. (d) Arginase is found in liver. It is very important enzyme for ornithine cycle.
47. (c) Bile has no digestive enzymes and hence, no chemical action on food.

### Digestive glands

1. (d) The endocrine part of pancreas is known as islets of Langerhans which contains 4 type of cell  $\alpha$ -cell,  $\beta$ -cells,  $\gamma$ -cells and  $\Delta$ -cell.
2. (d) Brunner's glands are present in the submucosa of duodenum and secrete  $HCO_3$ .
3. (a) Bile salts emulsify the fats and later on digested by enzyme lipase
6. (b) Parotid glands are one pair largest salivary gland which is situated below ear (pinna)
38. (b) In human body glycogen is stored in liver and muscles both total 400 gm. glycogen stored, 100 gm. in Liver and 300 gm. in muscles
39. (a) Gastric juice is secreted by gastric glands. It consist pepsin, rennin, lipase.
40. (d) Arginase is found in liver. It is very important enzyme for ornithine cycle.
47. (c) Bile has no digestive enzymes and hence, no chemical action on food.

48. (c) The chief function of bile is emulsification of fats and make easy digestion of fats.
49. (b) Pancreatic juice is secreted from pancreas its pH about 8.4.
50. (b) Glycogenesis and glycogenolysis both process found in liver.
52. (d) Bile juice synthesis in liver helps in digestion of fats but it does not contains any digestive juice so liver is a organ which does not produce any digestive enzyme.
56. (d) Intestinal juice contains many enzymes like maltase, sucrase, lactase etc.
57. (a) The largest gland in human body is liver.
60. (b) Caudate is the part of right lobe of liver.
61. (d) Daily secretion of saliva in man is about 1-1.5 lit.
62. (c) Lysozymes are found in saliva and tears both.

### Physiology of digestion

1. (d) Fructose is absorbed with the help of the carrier ions like  $\text{Na}^+$ . This mechanism is called facilitated transport.
3. (a) Lacteals are related with the absorption of fats are found in ileum.
4. (d) Pancreas is a digestive gland that secretes pancreatic juice. This juice acts on all type of food i.e., protein, starch, fat and nucleic acid. If pancreas is removed from the body, the digestion does not occur.
5. (c) Chylomicron's are fat droplets coated with glycerol and protein
7. (d) Trypsin is a protein digesting enzyme occur in pancreatic juice.
9. (a) Glycolysis is the first phase in the breakdown of glucose change in pyruvic acid occur in animal cell.
10. (c) A good source of lipase is pancreatic juice which is converted to fat into fatty acid + Glycerol.
11. (a) The end product of carbohydrate metabolism is  $\text{CO}_2$  and  $\text{H}_2\text{O}$ .
12. (c) Glycogen is a polysaccharide which is synthesized and stored in liver cell.
17. (a) Emulsified fat is digested by lipase enzyme which is secreted by pancreatic juice, and intestinal juice.
20. (d) Parietal or oxyntic cells release HCL required for the activation of pepsin.
23. (d) Digestion is defined as the conversion of non-diffusible food particle in diffusible food particle.
24. (b) Breaking of large fat droplets into fine emulsion by bile salt (Bile juice contain bile pigment and bile salt) of the liver.
26. (b) Because glucose is directly absorbed by the blood.
28. (a) Those enzyme who digest protein called proteolytic enzyme, these are trypsin, peptidase, pepsin.
30. (b) Rennin hydrolyses the milk protein casein into paracasein.
32. (c) Gluconeogenesis is the process in which glucose is formed from substance other than the carbohydrates.
35. (a) Trypsin and pepsin both are endopeptidase enzyme. Trypsin digest proteins in alkaline medium while pepsin digest protein in acidic medium.
39. (a) All lipid digestion takes place in the small intestine. Fatty acids and glycerol are the digestion products of lipids.
40. (a) Caecum is a small, pouch-like structure which ends into a tubular structure called vermiform appendix.

42. (a) Carbohydrate and fats (lipids) are chief energy source although proteins can also gives energy.

Macronutrient	Gross Caloric Value Kcal/g	Physiologic Value kcal/g
Carbohydrate	4.1	4
Protein	5.65	4
Fat	9.45	9

47. (a) Rennin enzyme is found in gastric juice. It is a milk coagulating proteinase. Rennin acts on casein (milk protein) and convert into calcium paracaseinate. It is known as curdling of milk.
48. (c) Because protein is primarily digested in the acidic media.
49. (d) Because human alimentary canal lacks cellulase enzyme and symbiotic micro-organisms.
54. (b) Enzyme erepsin is found in intestinal juice. It converts peptones to amino-acids.
57. (b) Bile salts help in the absorption of fats and fat soluble vitamin such as A, D, E and K in intestine.
58. (d) Fatty substance are emulsified by bile salts secreted by liver.

### Gastro intestinal hormones/Digestive enzymes

2. (d) Cholecystokinin-pancreozymin hormone is secreted by the epithelium of entire small intestine. It stimulates the gall bladder to release bile and pancreas to secrete and release digestive enzymes in the pancreatic juice.
5. (c) Most of proteases are secreted in inactive forms called proenzyme. Pepsin and trypsinogen both are inactive form of proteolytic enzyme.
7. (c) Secretin is secreted by the mucosa of duodenum and it stimulates the secretion of pancreatic juice and increase the duodenal movements. Thus it plays important role in digestion.
8. (d) Amylase is a starch splitting enzyme similar to ptyalin, hydrolysing starch and glycogen to maltose, isomaltose and limit dextrin.
9. (a) Isoenzymes are those enzymes which are found in more than one form having similar functions.
10. (c) Gastric glands are lined with three kinds of secreting cells zymogen (main, peptic or chief) cells, parietal cells and mucous cells. The main peptic or zymogen cells secrete digestive proenzyme namely pepsinogen and prorennin. HCl convert pepsinogen and prorennin into pepsin and rennin.
11. (d) Enteropeptidase or enterokinase is an enzyme involved in human digestion.  
Trypsin has an important role in the digestion of proteins in the anterior portion of the small intestine. It also activates other proteases in the pancreatic juice. Therefore in the absence of enterokinase the process of conversion of dipeptides to amino acids will be affected.
13. (a) Rennin is secreted by the cells of stomach in inactive form as prorennin and then activated to Rennin by HCl
16. (a) Bile is secreted by liver and stored in gall bladder.
18. (d) Pepsin initiates the digestion of protein in stomach producing proteoses and peptones.
20. (c) Pancreatic lipase (formerly called steapsin) hydrolyses fats into glycerol and fatty acids.
21. (b) Stored glycogen is broken down to glucose under the effect of glucagons secreted by alpha cells of Islets of Langerhans.

## 810 Digestion and Absorption

25. (d) Gastrin is a polypeptide hormone secreted by the pyloric mucosa which stimulates the stomach to release gastric juice.
26. (c) Cholecystokinin is a polypeptide hormone produced by the mucosa of the upper intestine which stimulates contraction of gall bladder.
28. (d) Renin is the hormone secreted by JGA in kidney. It is released due to hypotension (low BP).
30. (c) Trypsin an enzyme or enzyme complex is a part of pancreatic juice and is able to digest proteins in alkaline medium.
31. (a) Insulin is produced by  $\beta$  - cells of islets of Langerhans.
32. (b) Enterokinase is a gastro-intestinal enzyme secreted by small intestine of vertebrate, which converts trypsinogen to trypsin.
37. (a) Secretin hormone produced by duodenal mucosa which causes a copious secretion of pancreatic juice.
38. (a) Since amylase, rennin and trypsin are enzymes, therefore these all are proteins.
40. (c) The duodenal epithelium is stimulated to secrete secretin by the entry of acidic chyme into the duodenum.
42. (b) Succus entericus is the intestinal juice stimulated by secretin and cholecystokinin from the intestinal glands.
43. (c) It is a hormone secreted by the mucosa of small intestine.
23. (c) Essential amino acids are those which are taken from food, not synthesized in the body.
25. (d) Primary component of bones and also present in muscles and blood
29. (a) Thiamine ( $B_1$ ) deficiency is common in alcoholics. It leads to decreased mental function, double vision and reduced muscular contraction and the resulting disorder is known as Wernicke's syndrome.
30. (a) Steen Hoeck described that vitamin D is synthesized in presence of UV rays of sunlight in the skin.
31. (b) The vitamins are generally divided into Two major groups : Fat soluble (A, D, E and K) and water soluble (B - complex and C)
32. (d) Biotin or nicotinic acid consists of sulphur. It acts as coenzyme needed for protein and fatty acid synthesis,  $CO_2$  fixation and transamination.
33. (b) On the basis of their requirement in body the inorganic elements are of two types :
  - (i) **Macroelements** : C, H,  $N_2$  and  $O_2$  are called big four elements of living body because they are required in maximum amount in the body.
  - (ii) **Microelements** : Iron, iodine, manganese, copper, zinc, fluorine etc, are required in minimum amount in the body.
34. (d) Barium is not used in human body.

### Nutrition and Nutritional requirement

1. (a) Marasmus occurs due to prolonged malnutrition and deficiency of proteins and calories.
4. (a) Retinal pigment is an aldehyde of vitamin A.
10. (c) Proteins are broken down into amino acids during the process of digestion and finally all fats are converted into fatty acid, glycerol and monoglycerides.
11. (a) Proteins are made up of amino acid molecules, hence on hydrolysis they form amino acids.
14. (b) Carbohydrates are chief source of energy in the food of most of the animals. Main source of carbohydrates are cereals, fruits, milk rice, and potato.
16. (b) Casein is protein which form the part of food for the young animal. Best source of casein is milk.
18. (b) Carbohydrate are classified as :  
Monosaccharides (e.g., glucose, fructose, galactose), disaccharides (e.g., sucrose, maltose, lactose) and polysaccharides (e.g., starches, glycogen, cellulose, dextrins).
19. (c) Lactose ( $C_{12}H_{22}O_{11}$ ) is milk sugar. It is a disaccharide composed of glucose and galactose unit.
20. (b) The anhydrobonds of protein are called peptide bonds. A peptide bond is formed between carboxyl group of one amino acid and amino group of adjacent.
21. (b) Carbohydrates are more suitable for the production of energy in the body than proteins and fats. Carbohydrate are also stored in the body cells as glycogen and are used for the production of energy whenever required.
37. (a) Vitamin C is also called anti scorbutic factor and Ascorbic acid
42. (c) Vitamin C is heat labile.
44. (c) The term vitamin was given by Funk.
47. (b) Zinc takes part in immune reactions
55. (c) Deficiency of vitamin  $B_1$  causes beri-beri disease. Beri-beri disease was discovered by Eijkman in 1897.
60. (b) Fluorine maintains normal dental enamel and prevents dental caries.
64. (a) Vitamin A is synthesized in liver from yellow and red carotenoid pigments.
65. (c) The given symptoms occur due to deficiency of thiamine (vit.  $B_1$ ). Thiamine is a precursor of the coenzyme thiamine pyrophosphate which functions in carbohydrate metabolism. Deficiency leads to beriberi in humans and to polyneuritis in birds. Good sources include brewer's yeast, wheat germ, beans, peas and green vegetables

66. (b) Because vitamin K helps in maintenance of normal prothrombin and factor VII in the blood and thus takes part in normal coagulation.
69. (d) As both vitamin  $B_{12}$  and folic acid are involved in maturation of erythrocytes in bone marrow.
75. (d) Vitamin E maintains normal functioning of reproductive organs hence it is called fertility vitamin. Sterility (impotence) and muscular atrophy is common deficiency disease of vitamin E.
79. (c) Vitamin  $B_{12}$  is a dark red compound containing cobalt.
80. (d) Vitamin D also known as calciferol. The deficiency of calciferol causes, the children suffer from rickets and adult from osteomalacia.
81. (b) Vitamin A occurs in yellow vegetables and fruits like carrots, tomatoes, papaya and mango, green leafy vegetables as spinach.
84. (b) Vitamin  $B_{12}$  is not found in plants. However it is considered that *spirulina* (an algae) contain  $B_{12}$ . Vitamin  $B_{12}$  is synthesized by intestinal bacteria which infact are main source of vitamin  $B_{12}$ . Many micro-organisms (bacteria) of the stomach of ruminant mammals also synthesize large quantities of vitamin  $B_{12}$ .
88. (b) Vitamin E is also called as tocopherol or antifertility vitamin.
89. (c) Nicotinic acid or vitamin  $B_3$  is a pellagra preventing factor or PP factor. Pellagra caused due to the deficiency of vitamin  $B_3$  is characterized by dermatitis (thick, pigmented skin), muscle atrophy and severe inflammation of mucous membrane of mouth.
90. (c) Vitamin  $B_{12}$  is also called cyanocobalamine. It is essential for the formation and maturation of erythrocytes.
98. (c) It increases the RBC count and the platelets through its action on the bone marrow. It promotes haemopoiesis.
100. (c) Vitamin  $B_{17}$  has been recently explained to be found in water melon. It is supposed to have anti cancer property.
109. (b) Vitamin-C (Ascorbic acid) play an important role in certain metabolic reactions. This vitamin activates an enzyme that is involved in synthesis of hydroxy proline which is an integral part of collagen. Obviously it is essential for formation and growth of connective tissues cartilage, bone, teeth etc.
110. (c) Since vitamin K helps in blood clotting, its deficiency will lead to excessive bleeding.
112. (c) Paralysis of muscle fatigue and burning feet syndrome is related with deficiency of pantothenic acid (vitamin  $B_3$ ).
114. (c) In man, attached to caecum is a twisted, coiled tube, measuring about 3 inches in length, called the vermiform appendix. Inflammation of the vermiform appendix is called appendicitis.
115. (a) It takes part in the formation of coenzyme FMN and FAD.
116. (a) *Nutrition or food intake in paramecium of nutrition in amoeba is holozoic that is, amoeba is heterotrophic.*
119. (a) A young man requires approximately 3000K. cal. per day while a child of about 15 years requires 2500 and infant of 4-6 years requires about 1500 Kcal per day.
122. (b) It also maintains the integrity of epithelial tissue and prevents the infection.
124. (d) Vitamin C is necessary for formation of collagen fiber, in this way vitamin C helps for healing to the wound.
127. (a) Vitamin A was discovered by Mc collum and Davis (1915) from butter and egg yolk.
129. (c) The activity of vitamin E is destroyed by U.V. rays and oxidation.
130. (d) E.coli lives in mutual association in human colon as it obtains food from the intestine and in turn help to produce vitamin  $B_{12}$ .
133. (b) It acts as the coenzyme of pyruvate carboxylase. Its active factor is thymine pyrophosphate. It causes decarboxylation of pyruvic acid.
134. (a) Beri-beri is caused by deficiency of vitamin  $B_1$  (thiamine)
136. (a) The chemical name of vitamin  $B_1$  is thiamine. It can be synthesized by bacteria inside the gut
137. (b) Because riboflavin is an orange-yellow compound, so cow's milk appears slightly yellowish
139. (c) Vitamin K (phyloquinone) is required for the formation of clotting factors by liver, thereby its deficiency leads to delay in coagulation i.e. haemorrhage.
141. (a) Proteins are large molecules of high molecular weight containing C, H, O and nitrogen (N). The presence of N distinguishes them from carbohydrate and fat. Iron, copper, iodine, sulphur and phosphorus may also be present in a very low proportion. Proteins are found in fish, meat, egg, wheat, bean, ground-nut and pulses.
143. (c) Lactose or milk sugar is a disaccharide formed by the union of one molecule of galactose and one molecule of glucose. Besides milk it is found in flowers of some plants
145. (c) Vegetable oil contains low molecular weight lipids.
146. (b) Copper takes part in haemoglobin synthesis.
147. (b) Primary anaemia is due to deficiency of Fe
148. (d) Amoeba takes solid food and digests it intracellularly.
150. (d) Euglena carries on both autotrophic and hetrotrophic modes of nutrition.

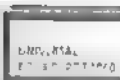
### Critical Thinking Questions

3. (c) The mucosa is highly folded and the single-layered mucous membrane of the infoldings forms tubular and often branched gastric gland in the lamina propria. Each gland has three types of secretory cells – neck cells, oxyntic cells, zymogen cells.

4. (d) Generally, fatty acids upto a chain length of 10 carbon atom are primarily absorbed through the blood capillaries, but those with higher chain length through lymphatic route (lymph vessels).
6. (b) The bile is a complex greenish and alkaline fluid. Containing bile salt and bile pigment. Most important bile pigment is bilirubin which is a breakdown product of hemoglobin, biliverdin is absent.
10. (d) Odour of faeces is due to presence of toxic amines indole and skatole derived from action of bacteria on amino acid. Gases also causes odour in faeces. They are produced by fermentation of carbohydrate.
11. (a) A lipoprotein is a biochemical assembly that contains both proteins and lipids. There are several types of lipoproteins, each having different functions, but all essentially are transport vehicles. Lipoproteins are categorized and named mainly accordingly to their density which varies with the ratio of lipids to proteins from largest and highest to smallest and heaviest, the four major classes of lipoproteins are chylomicrone, VLDL, LDL and HDLs.
12. (a) Caecum is small blind sac which host some symbiotic micro-organism.
14. (d) Enterogastrone is secreted by the duodenal epithelium. It inhibits gastric secretion and motility.
15. (c) Well established gastrointestinal hormones are – i. secretin, ii. CCK, iii. Gastrin, iv. GIP, v. Motilin.
16. (c) Enterocrinin is secreted by the epithelium of entire small intestine. It stimulates the crypts of lieberkuhn to release enzymes it to the intestinal juice.
18. (a) Third molars in human being are called wisdom teeth. Number of 3<sup>rd</sup> molar in both jaw is four.
20. (c) Glycogen is a branched polymer of glucose. It is stored mostly in muscles and liver of animal and it is also called animal starch.
21. (b) In the presence of enterokinase, inactive trypsinogen is converted into active trypsin.
23. (d) Vitamin K is also known as antihæmorrhagic vitamin.
26. (b) Vitamin C promote wound healing.
27. (d) Pellagra is a disease caused by the deficiency of nicotinamide or nicotinic acid or niacin or vitamin B<sub>3</sub>. It is frequent among people eating food with low tryptophan content. The symptoms of pellagra are inflammation of skin, diarrhoea and dementia.
28. (a) Riboflavin (vitamin B<sub>2</sub>) causes cheilosis, which is characterized by inflammation and cracking at the angles of the mouth
30. (a) Triglyceride molecule is completely hydrolyzed into three molecules of fatty acid + one molecule of glycerol.
32. (d) Kwashiorkor is caused by the deficiency of proteins in diet this disease occurs in children of age group 1 to 5 years.
33. (b) Intestinal villi are mainly concerned with absorption. Villi are absent in stomach
34. (c) Empty stomach is lined with folds called rugae.
35. (d) Auerbach's plexus is a part of autonomic nervous system in vertebrates lying between the two main muscular layers of intestine and controlling its peristaltic movements.
38. (d) Digestion in human is extracellular (intercellular).
40. (b) The entire small intestine has circular folds of the mucous membrane, the 'valves' of kerkring. These folds are more prominent in the jejunum.
42. (c) The blood carries from digestive tract to liver through hepatic portal vein the blood which comes from the digestive tract contains absorbed food like glucose and amino acids.
43. (a) Glucose and galactose are absorbed by active transport. Fructose is absorbed by facilitated diffusion.
46. (d) Physiological value of carbohydrates is 4.0 kcal/g of proteins 4.0 kcal/g and of fats is 9.0 kcal/g  
Hence  
5 g raw sugar will yield  $5 \times 4.0 = 20.0 \text{ kcal}$   
4 g albumin (protein) will yield  $4 \times 4.0 = 16.0 \text{ kcal}$   
10 + 2 g of fat will yield  $12 \times 9.0 = 108.0 \text{ kcal}$   
Total yield = 144 kcal.
49. (c) Pituitary gland is located in bony depression called sella turcica in sphenoid bone of cranium

### Assertion and Reason

1. (a) In liver, glycogen a reserve food material is changed into glucose (glycogenolysis) and released into blood. Under abnormal conditions, liver can convert proteins and fats into glucose by complex chemical reactions i.e., called gluconeogenesis. Thus, due to hepatectomy blood sugar level falls rapidly.
2. (d) Fatty acids which lack any double or triple bond in their hydrocarbon chain are known as saturated fatty acids. Example lauric acid, arachidic acid, myristic acid, palmitic acid, stearic acid etc in contrast to saturated fatty acids, unsaturated fatty acids have one or more double bonds between carbon atoms at fixed place along the hydrocarbon chain. Example palmitoleic acid, oleic acid, linoleic acid, linolenic acid, arachidonic acid etc.
3. (c) Ruminant animals such as cattle, buffalo, sheep, goat and camel have a compound stomach, which consists of four chamber, viz, rumen, reticulum, omasum and abomasum. Rumen is the first and the largest of the four chambers. Rumen and reticulum harbour numerous bacteria and protozoa, which carry out extensive fermentation of cellulose. So, these two chambers function as sites for cellulose digestion in ruminants. The gastric juice containing enzymes and HCl is secreted only by the fourth chamber i.e., Abomasum.



4. (c) Numerous tube like glands are present in the wall of small intestine which secrete intestinal juice into the intestinal lumen. This juice contains a number of enzymes like enterokinase, aminopeptidases, dipeptidases, maltase, lactase, lipase etc. for digesting various types of food. On the other hand, the enzymes RNAse and DNAse are present in the pancreatic juice. These enzymes are secreted by the pancreas and are drained into the small intestine via Hepato pancreatic duct.
5. (d) Minerals take part in biological reactions and are thus biologically active. Anaemia is caused by deficiency of iron.
6. (a) Thick layer of muscles are present in the alimentary canal. These muscles facilitate the movement of food particles through alimentary canal. Large food particles are broken down into small, semi liquid particles by the action of these muscles. Later also help in the forward flow of food materials and mixing of enzymes coming from different glands related to alimentary canal.
7. (e) Alcoholic fermentation is the respiration in absence of  $O_2$ . In this process, hexose molecule is changed to ethyl alcohol and  $CO_2$ . In presence of zymase enzyme. In this less amount of energy is released as compared to aerobic respiration.
8. (e) Insulin is secreted by  $\beta$ -cells of Islets of Langerhans. It helps in conversion of glucose into glycogen decreasing blood sugar level. This is called glycogenesis.
9. (b) Carbohydrates are more suitable for the production of energy in the body than proteins and fats, because carbohydrate molecules contain relatively more oxygen than the others, and consequently, requires less molecules of oxygen for their oxidation. In other words, for each litre of oxygen consumed, carbohydrates yield far more energy than proteins or fats. Carbohydrates are also stored in the tissue as glycogen for use in the production of energy, when necessary. Glycogen is the stored fuel particularly in such tissues as skeletal muscles which then have to work with a supply of oxygen far lower than their immediate need.
10. (c) Non essential amino acids are those amino acids which need not be supplied in the diet because they can be synthesised by the body, particularly from carbohydrate metabolites, Glycine is one such non essential amino acid. On the contrary, essential amino acids are those amino acids which can not be synthesised in the animal body and must be supplied with food in adequate amounts. Out of twenty amino acids, eight are considered essential in human diet
11. (a) Ascorbic acid is called vitamin C. The deficiency of this vitamin causes scurvy
12. (c) In small intestine Pancreatic amylase converts starch and dextrins into maltoses and small intestine is main site for digestion of carbohydrates.
13. (d) In liver, alcohol is oxidised into acetaldehyde which is further oxidised into acetate. The latter is converted to acetyl coenzyme A which is used in Krebs' cycle.  
Ethyl alcohol  $\rightarrow$  Acetaldehyde  $\rightarrow$  Acetate  $\rightarrow$  Acetyl Co A  $\rightarrow CO_2 + H_2O$
14. (a) The human being is the only mammal who ingests significant amount of lactose in milk. Curiously, many human adults can not digest milk, because with age they produce little or no lactase in the intestinal juice. In such persons, the lactose of milk remains undigested and is fermented in the intestine producing gases and acids. This results in flatulence, intestinal cramps and diarrhoea.  

Adult human  
 $\downarrow$   
Less or no lactase  
 $\downarrow$   
Lactose remains undigested  
 $\downarrow$   
Undigested substances fermented  
 $\downarrow$   
Produce gas, acids, intestinal cramps, diarrhoea
15. (a) Trypsin is protein digesting enzyme present in the intestine of animals. Though it cannot digest casein (a milk protein), in predator animals drinking the blood of their prey, trypsin hydrolyses fibrinogen of blood into fibrin, leading to blood coagulation thus help in blood digestion. It also activates other pancreatic proteases.
16. (a) If sea water is drunk, its  $Mg^{2+}$  ions increase the solute concentration in the intestinal lumen because  $Mg^{2+}$  is absorbed very slowly. On the contrary,  $Mg^{2+}$  draws water from the blood to the intestinal lumen by osmosis. So, water is not gained, but is lost from the blood on drinking sea water. Thus, there occurs increase in the fluidity and volume of intestinal contents, in the same way this consequently stimulates intestinal peristalsis and evacuation of fluid faeces.
17. (a) Sea faring fisherman suffer from paralysis because raw fish muscles contain an enzyme which destroys Vitamin  $B_{12}$ .
18. (d) Starch is hydrolysed by pancreatic amylase to maltose, isomaltose and dextrins sucrose  $\xrightarrow{\text{SUCROSE}}$  glucose and fructose.
19. (b) The body temperature in cold blooded varies with that of the environment as there is no fat deposition. On the other hand, cold blooded animals use fat during hibernation to carry out their metabolic processes.
20. (e) Absorption takes place in small intestine as it offers large surface area for absorption. Stomach produces the hormone gastrin and intrinsic factor.



## Digestion and Absorption

## ET Self Evaluation Test

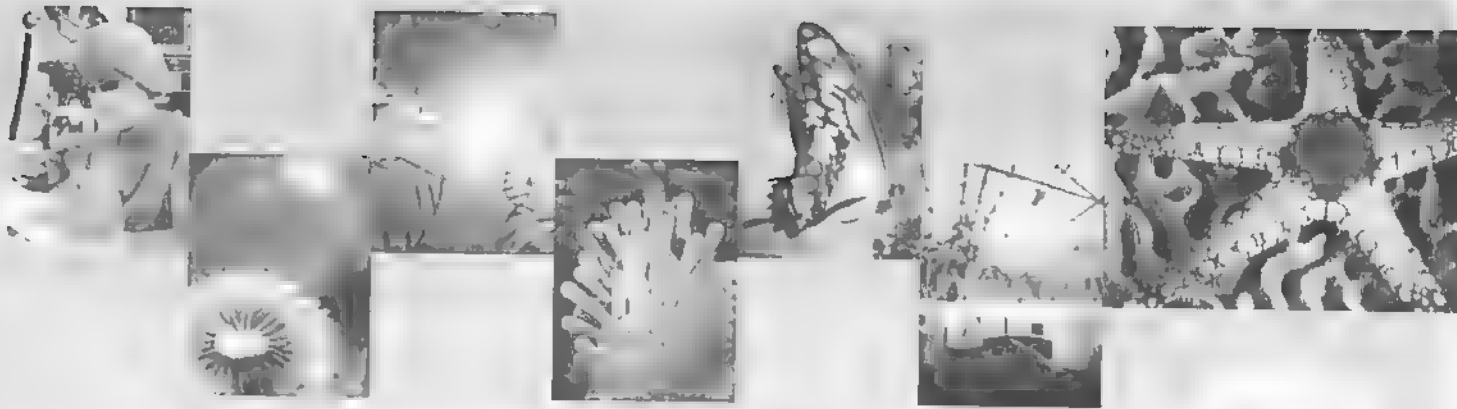
1. Find out the correctly matched pair [Kerala PMT 2007]  
 (a) Pepsinogen - Zymogenic cells  
 (b) HCl - Goblet cells  
 (c) Mucous - Oxyntic cells  
 (d) Pancreatic juice - Salivary glands  
 (e) Ptyalin - Acinar cells
2. A dental disease characterized by mottling of teeth is due to the excess of a certain chemical element in drinking water. Which of the following is that element [BHU 2000]  
 (a) Mercury (b) Chlorine  
 (c) Fluorine (d) Boron
3. Spot the salivary gland among the following [KCET 1999]  
 (a) Sublingual (b) Adrenal  
 (c) Brunner (d) Lacrymal
4. Excess carbohydrates and proteins are stored in the body as [DUMET 2010]  
 (a) Amino acids (b) Fats  
 (c) Starch (d) Monosaccharide
5. The colour of the faeces is due to the  
 (a) Urochrome (b) Stercobilin  
 (c) Biliverdin (d) Bacteria
6. Which one is detritus feeder [RPMT 2000]  
 (a) Parrot (b) Sheep  
 (c) Unio (d) Dung beetle
7. Lamina propria is related with  
 (a) Human intestine (b) Liver of human being  
 (c) Graafian follicle (d) Acinus of pancreas
8. How many teeth in man grows twice in life [JIPMER 2001; AFMC 2002, 04]  
 (a) 32 (b) 28  
 (c) 20 (d) 12
9. Find out the correct match
- |    | Column - I           |    | Column - II            |
|----|----------------------|----|------------------------|
| A  | Hepatic lobule       | 1. | Sub mucosal glands     |
| B  | Brunner's glands     | 2  | Base of villi          |
| C. | Crypts of Lieberkuhn | 3  | Glisson's capsule      |
| D  | Sphincter of Oddi    | 4  | Gallbladder            |
| E. | Cystic duct          | 5. | Hepato-pancreatic duct |
|    |                      | 6  | Serous glands          |
- [NCERT; Kerala PMT 2007; J & K CET 2008]  
 (a) A-3, B-6, C-2, D-5, E-4  
 (b) A-5, B-2, C-3, D-6, E-1  
 (c) A-3, B-1, C-2, D-5, E-4  
 (d) A-4, B-6, C-5, D-2, E-1  
 (e) A-4, B-2, C-6, D-5, E-3
10. By the mechanical stimulation on the wall of stomach, a hormone is released. This is  
 (a) Gastrin (b) Progesterone  
 (c) Secretin (d) Pancreozymin
11. Insulin, epinephrine, glucagon collectively influence  
 (a) Glyconeogenesis  
 (b) Glycerophosphate shuttle  
 (c) Glycolysis  
 (d) Glycogenolysis and glycogenesis
12. Match the item in Column I (vitamins) with those in Column II (deficiency diseases)  
**Column I**  
 (Vitamins)  
 I. K  
 II. D  
 III. B<sub>1</sub>  
 IV. A<sub>1</sub>  
**Column II**  
 (Diseases)  
 A. Beri-beri  
 B. Haemorrhagic disease in new born  
 C. Night blindness  
 D. Rickets  
 Which one of the following is the correct matching of all the four vitamins [CBSE PMT 1995; MP PMT 1999, 2002; DPMT 2006]  
 (a) I-C, II-B, III-D, IV-A (b) I-A, II-B, III-D, IV-C  
 (c) I-C, II-A, III-D, IV-B (d) I-B, II-D, III-A, IV-C
13. Pernicious anaemia is caused due to the deficiency of [MP PMT 2009; WB JEE 2009]  
**Or**  
 This vitamin is also known as "Castle's extrinsic factor"  
 (a) Folic acid (b) Vitamin B<sub>6</sub>  
 (c) Vitamin B<sub>12</sub> (d) Appendix
14. Exclusive holozoic nutrition is seen in [Odisha JEE 2011]  
 (a) Spider (b) Man  
 (c) Housefly (d) Shark
15. Symbiotic bacteria present in intestine of most primates, which synthesize certain vitamins are  
 (a) *Entamoeba histolytica*  
 (b) *Entamoeba coli*  
 (c) *Entamoeba gingivalis*  
 (d) None of these

## AS Answers and Solutions

1	a	2	c	3	a	4	b	5	b
6	c	7	a	8	c	9	c	10	a
11	d	12	d	13	c	14	b	15	b

2. (c) Excess intake of fluorine causes fluorosis, which is manifested in its mild state by mottled teeth and in a more severe state by enlarged bones.
3. (a) In human, 3 pairs of salivary glands are present. They are sublingual, parotid and submaxillary.
5. (b) It is an oxidation product of bile pigment.
6. (c) Animal which feeds upon organic matter mixed with the soil e.g. earthworm and unio.
8. (c) In man, 20 teeth are diphyodont, i.e., grow twice in life.
11. (d) Epinephrine and glucagon cause glycogenolysis while insulin causes glycogenesis.
13. (c) Pernicious anaemia marked by a decrease in the number of red blood cells which is caused by a reduced ability to absorb vitamin B<sub>12</sub>.
15. (b) *Escherichia coli* is common colon bacteria found in human beings and many vertebrates. This bacteria is normally not harmful but is mostly helpful in digestion through synthesis of vitamin.





## Chapter 5.2

# Breathing and Exchange of Gases

Cells continually use oxygen ( $O_2$ ) for the metabolic reactions that release energy from nutrient molecules and produce ATP (Adenosine Tri Phosphate). At the same time, these reactions release carbon dioxide. Since an excess amount of  $CO_2$  produces acidity that is toxic to cells, the excess  $CO_2$  must be eliminated quickly and efficiently. The two systems that cooperate to supply  $O_2$  and eliminate  $CO_2$  are the cardiovascular system and the respiratory system. The respiratory system provides for gas exchange, intake of  $O_2$  and elimination of  $CO_2$ , whereas the cardiovascular system transports the gases in the blood between the lungs and body cells.

## Respiration

Respiration is a process which involves intake of oxygen from environment and deliver it to the cells. It includes stepwise oxidation of food in cells with incoming oxygen, elimination of  $CO_2$  produced in oxidation, *release of energy during oxidation* and storing it in the form of ATP. It takes place in three basic steps –

(1) **Pulmonary ventilation** : The first process, pulmonary (*pulmo* = lung) ventilation, or breathing, is the inspiration (inflow) and expiration (outflow) of air between the atmosphere and the lungs.

(2) **External (pulmonary) respiration** : This is the exchange of gases between the air spaces of the lungs and blood in pulmonary capillaries. The blood gains  $O_2$  and loses  $CO_2$ .

(3) **Internal (tissue) respiration** : The exchange of gases between blood in systemic capillaries and tissue cells is known as internal (tissue) respiration. The blood loses  $O_2$  and gains  $CO_2$ . Within cells, the metabolic reactions that consume  $O_2$  and give off  $CO_2$  during production of ATP are termed cellular respiration.

## Respiratory surface

The surface at which exchange of gases ( $CO_2$  and  $O_2$ ) takes place is called respiratory surface. Respiratory surface must be

vascular and have enough area for gas exchange. For example – plasma membrane in protozoa, body wall (skin) in annelids, alveocapillary membrane in men.

## Respiratory medium

Oxygen is dissolved in air and water. Thus water and air are source of oxygen for animals and called respiratory medium. Water and air are external respiratory medium. Inside the body an internal respiratory medium is also found. This internal respiratory medium is tissue fluid

**Types of respiration** : It is of two types

(1) **Aerobic respiration** : It occurs in the presence of molecular oxygen. The oxygen completely oxidizes the food into carbon dioxide and water, releasing large amount of energy. The organisms showing aerobic respiration, are called aerobes. It is found in most of animals and plants. Aerobic respiration is of two main types direct and indirect.



(i) **Direct respiration** : It is the exchange of environmental oxygen with the carbon dioxide of the body cells without special respiratory organs and without the aid of blood. It is found in aerobic bacteria, protists, plants, sponges, coelenterates, flatworms, roundworms and most arthropods.

(ii) **Indirect respiration** : It involves special respiratory organs, such as skin, buccopharyngeal lining, gills and lungs, and needs the help of blood. The respiration in the skin, buccopharyngeal lining, gills and lungs is respectively called cutaneous buccopharyngeal, bronchial and pulmonary respiration. Cutaneous respiration takes place in annelids, some crustaceans, eel fish, amphibians and marine snakes. It occurs both in water and in air. Buccopharyngeal respiration is found in certain amphibians such as frog and toad. It occurs in the air. Bronchial respiration is found in many annelids, most crustaceans and

molluscs, some insect larvae, echinoderms, all fishes and some amphibians. It occurs in water only. Pulmonary respiration is found in snails, pila, some amphibians and in all reptiles, birds and mammals. It takes place in air only.

(2) **Anaerobic respiration** : It occurs in the absence of molecular oxygen and is also called fermentation. In this, the food is only partially oxidised so only a part of energy (5%) is released and of energy remains trapped in the intermediate compounds. It is found in lower organisms like bacteria and yeast. It is also found in certain parasitic worms (*Ascaris*, *Taenia*) which live in deficient medium. The organism showing anaerobic respiration, are called anaerobes. These involve one of following reactions.



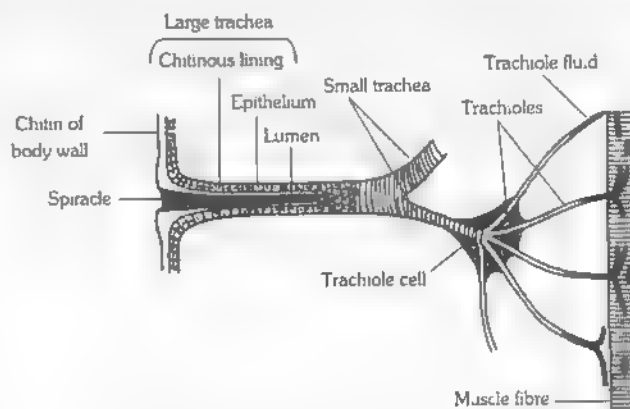
Certain body tissues of even aerobes also show anaerobic metabolism e.g., during the vigorous contraction of skeletal muscle fibres. In this, the glucose is metabolised into the lactic acid in anaerobic conditions. The rapid formation and accumulation of lactic acid are responsible for muscle-fatigue. The mammalian RBCs shows anaerobic respiration as these lack the mitochondria. In lens of eye and cornea of eye respiration is anaerobic because these structures are non vascular. Anaerobic respiration appeared first in primitive organisms because there was absence of  $O_2$  in primitive atmosphere.

## Respiratory organs

(1) **Skin** : Respiration by skin is called cutaneous respiration. Skin is the only respiratory organ in most annelids (earthworm and leeches) and an additional respiratory organ in amphibians (Toads and frogs). Skin should be thin, moist, naked, permeable and well vascular for respiration. For cutaneous respiration animal should have large surface area then its volume and should have relatively inactive life to minimize the use of oxygen. Some marine annelids such as sandworms (nereis) have parapodia (locomotory appendages) for respiration. In frog 100% cutaneous respiration during hibernation. In all marine snakes 20% respiration by skin.

(2) **Tracheae** : In insects, peripatus centipedes and millipedes tracheae are found for respiration. Tracheae are complex system of whitish, shining, intercommunicating air tubules. Tracheae are ectodermal air tubes. In cockroaches, three pairs of longitudinal tracheal trunks are present all along the length of body which are further connected with each other with the help of transverse branches. The main tracheae give off smaller tracheae whose branch repeatedly form a network of trachioles throughout the body. Trachea internally lined by chitinous cuticle called intima, which spirally thickened to form taenidae. Trachioles without taenidae, trachioles lined by trachein protein. From each tracheal trunk three branches come out. The dorsal branch is supplied to

the dorsal muscles where as ventral one to nerve cord and ventral muscles and middle one to the alimentary canal.



**Fig : 5.2-1 Trachea of cockroach**

(3) **Book lungs and book gills :** Spiders ticks, mites and scorpion (belongs to class arachnida) have book lungs for respiration. In scorpion 4 pairs of book lungs are present. A book lung is a chamber containing a series of thin vascular, parallel lamellae arranged like the pages of book. Book gills are found in marine king crab or horse shoe crab.

(4) **Gills** : Aquatic animals such as prawn, unto, fishes, sea stars and tadpoles respire by gills. Respiration by gills called bronchial respiration. Gills are of two types –

(i) **External gills** : External gills are found in arenicola (lug worm), larvae of certain insects e.g. damsel fly and some amphibians e.g. necturus, siren, proteus, frog tadpole first develop external gills which are replaced by internal gills later.

(ii) **Internal gills** : The internal gills may be phyllobranch (prawn), monopectinata (pila) eulamellibranch (unio), lamellibranch, filibranch (pisces). In all fishes, gills are hemibranch or demibranch and holobranch. In gills, gill lamellae are found which have capillary network. Water is drawn into gills → blood flowing in the capillaries of gill lamellae absorb oxygen from water and release  $\text{CO}_2$  → water containing  $\text{CO}_2$  is thrown out from gills. The 80% of  $\text{O}_2$  of incoming water is absorbed.

**Table : 5.2-1 Oxygen content of respiratory media**

Respiratory media	Oxygen content
Air	209.5 ml./l.
Fresh water at 25°C	5.8 ml./l.
Fresh water at 5°C	9.0 ml./l.
Sea water at 5°C	6.4 ml./l.

(5) **Buccopharyngeal lining** : Frog breathes by buccopharyngeal lining of buccopharyngeal cavity. This is called buccopharyngeal respiration.

Table : 5.2-2 Respiratory organs of animals

Animals	Respiratory organs
Protists, Bacteria	Direct respiration through plasma membrane
Porifera	Plasma membrane of each cell
Coelenterates	General body surface
Platyhelminthes ( <i>Fasciola hepatica</i> , tapeworm)	Anaerobic
Nematodes ( <i>Ascaris</i> )	Anaerobic
Annelids (Earthworm and Leeches)	Skin
Nereis	Parapodia
Insects	Trachea
Centipedes	Trachea
Millipedes	Trachea
Spider and Scorpion, ticks, mites	Book lungs
Marine king crab	Book gills
Prawns, Unio and Pila	Gills
Echinodermata	Dermal branchiae, Tube feet, Respiratory tree, Bursae
Fishes, Tadpoles	Gills
Frogs, Toads	Buccopharyngeal lining, Lungs, Skin
Reptiles, Mammals	Lungs
Birds	Air sacs/Lungs
Lung fish	Air bladder.
Urochordata ( <i>Herdmania</i> )	Test
Marine turtle	Cloacal respiration
Mollusca (Unio)	Mental

## Respiratory system of human

Human respiratory system is derived from endoderm. Human respiratory system may be divided into two components –

- (1) Respiratory tract or conducting portion
- (2) Respiratory organs

(1) **Respiratory tract or conducting portion** : It is the passage for the air. In this part gaseous exchange does not takes place. It is also called dead air space. It is divided in following parts –

(i) **Nose** (Latin-Nasa) (Greek-Rhine) : Cavity of nose is called nasal cavity. Nasal cavity is divided into two parts by nasal septum called mesethmoid. Each part is called nasal chamber. Each nasal chamber opens out side by external nares. Nasal septum has two part. First part is small and is made of cartilage (hyaline). Second part is major and it is bony. Vomer is the main bone. Each nasal chamber has three region.

(a) **Vestibular region** : Vestibular region also known as vestibule is lined by non keratinized squamous epithelium, it is ectodermal in origin and have sebaceous gland, sweat gland and hair. Vestibule is also found in inner air larynx, mouth and vagina. It acts like a sieve to check the entry of large dust particles and other things.

(b) **Respiratory region** : Middle region lined by respiratory epithelium which is ciliated pseudostratified columnar epithelium. It contains mucus and serous cells. Mucus cells produce mucus and serous cells produce watery fluid. Respiratory epithelium is highly vascular and appears pink or reddish. Respiratory region acts as a

air conditioner and makes the temperature of in going air nearly equal to body. It also acts as a filter not give entry to dust particles, flies or mosquitoes.

(c) **Olfactory region** : It is upper region. It is lined by olfactory epithelium. This is also called Schneiderian epithelium. Olfactory region is the organ of smell and detect the odour of inspired air. Inspiration is stopped if odour of air is foul or offensive. According to new researches pheromone receptors are found in nasal cavities

(ii) **Nasal conchae** : Lateral wall of nasal cavity have three shelves like structures called conchae or turbinate. 3 pairs of nasal conchae are found. Nasal conchae are covered with mucus membrane. They increase the surface of nasal chamber. Both the chambers of nasal cavity open into nasopharynx by their apertures called internal nostrils or conchae. Adjacent to internal nostril there are opening of eustachian tube. Names of these three conchae and names of the bones that form them are given below.

(a) **Superior conchae** : The dorsal most chochae is supported mainly by nasal bone called nasoturbinate. It is the smallest conchae.

(b) **Middle conchae** : Ethmoid bone called ethmoturbinate.

(c) **Inferior conchae** : The ventral most conchae supported by maxilla bone called maxilloturbinate. It is a separate bone itself.

(iii) **Pharynx** : It is the short vertical about 12 cm long tube. The food and air passages cross here. It can be divided in 3 parts –

(a) **Nasopharynx** : Nasopharynx is only respiratory upper part in which internal nares open. There are 5 opening in its wall; two internal nares, two eustachian tube opening and one opening into oropharynx.

(b) **Oropharynx** : Middle part is called oropharynx. In this part oral cavity open known as fauces. Two pair tonsils the palatine and lingual tonsils are found in the oropharynx.

(c) **Laryngopharynx or hypopharynx** : Lowest part is called laryngopharynx. It leads into two tubes. One at the front is wind pipe or trachea and one at the back is food pipe or oesophagus. Both oro and laryngo pharynx is both a respiratory and a digestive pathway.

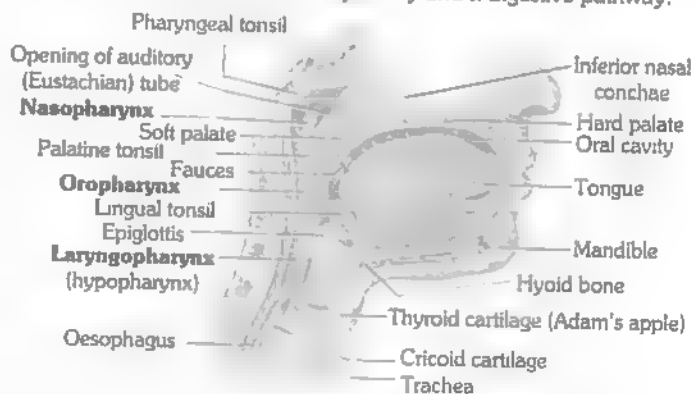


Fig : 5.2-2 Sagittal section showing the regions of the pharynx

Nasopharynx is lined by ciliated pseudostratified epithelia, oropharynx and laryngopharynx are lined by non keratinized epithelium. Pharynx is lined by non keratinized stratified squamous epithelium. This epithelium is ciliated in nasopharynx. Mouth serves as an alternate route for air when nasal chambers are blocked. Foramen by which pharynx opens into larynx called

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glottis. In general it remains open. During swallowing it is closed. It provides passage for air. Pharynx leads into the oesophagus through an aperture called gullet. In general condition it remains closed and opens at the time of swallowing. During swallowing epiglottis closes the glottis.

(iv) **Larynx or Voice box** : It is found both in frogs and rabbits. Larynx does not help in respiration. It is present on tip of trachea and is made up of 9 cartilages such as thyroid (single) has a prominence called pomum admi or adam's apple, cricoid (single), arytenoid (paired), are piece of hyaline cartilage. While epiglottis (single), carniculate (paired), cuneiform (paired), santorini are piece of elastic cartilage. Clinically, the cricoid cartilage is the landmark for making an emergency air way.

Larynx is a short tubular chamber and opens into the laryngopharynx by a slit like aperture called glottis. Glottis always remains open except during swallowing. Larynx is more prominent in men than women due to male hormone. Before puberty, the larynx is inconspicuous and similar in both sexes. Larynx is a voice producing instrument. For this purpose larynx have two types of vocal cord. In birds voice producing organ is syrinx, found at lower end of tracheae.

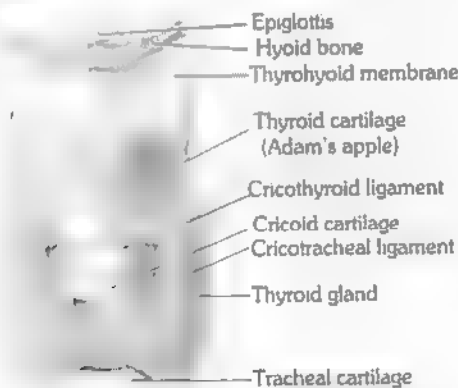


Fig : 5.2-3 Larynx (Anterior view)

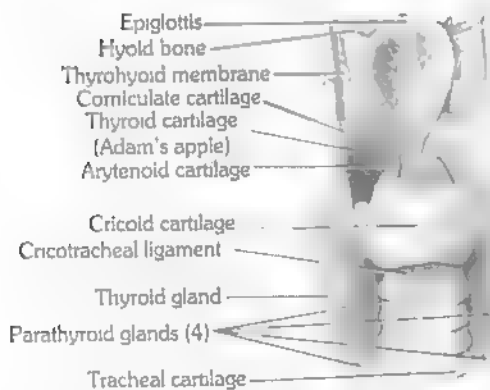


Fig : 5.2-4 Larynx (Posterior view)

(a) **False vocal cord or vibrating fold or anterior vocal cord** : These are folds of mucus membrane. Gap between them is called rema vestibuli. These are not responsible for sound production. In elephants only true vocal cords are present and are responsible for this trumpet sound.

(b) **True vocal cord or posterior vocal cords** : They are made up of yellow elastic fibres. Gap between them is called rema glottidis or peep hole. In males the length of true vocal cord is 2.25 cm and in female is 1.75 cm. Sound produced by rabbit is called

quaking. Hippopotamus lacks true vocal cords. Pitch is controlled by the tension of vocal folds.

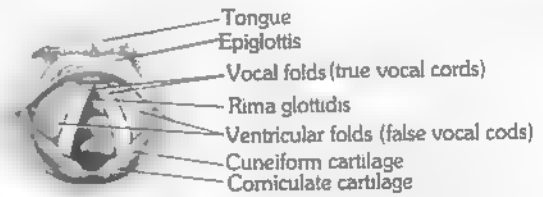


Fig : 5.2-5 Movement of vocal folds apart (abduction)



Fig : 5.2-6 Movement of vocal folds together (adduction)

(v) **Trachea** : It is a tubular structure of about 12 cm. in length and 2.5 cm in diameter. The wall of trachea is made of fibres, cartilage muscles and the mucus membrane. In middle of thorax at the level of 4<sup>th</sup> and 5<sup>th</sup> thoracic vertebra divides it into two branches called right and left primary bronchi. Further division of primary bronchi is given in form of arrow diagram.

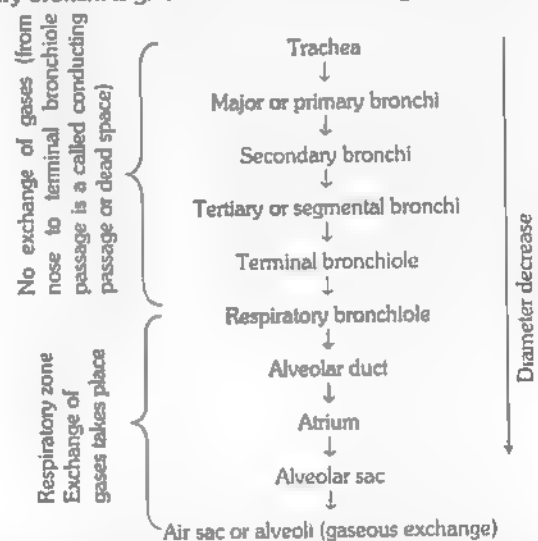


Table : 5.2-3 Different epithelium lining in respiratory tract

Vestibular region of nose	Skin having hair
Respiratory region of nose	Ciliated pseudostratified
Olfactory region of nose	Olfactory (Schneiderian) epithelium
Pharynx (Oropharynx, Laryngopharynx)	Non-keratinised stratified squamous
Trachea and bronchi (Upper)	Pseudostratified ciliated columnar epithelium with mucus cells
Lower bronchi (Secondary / Tertiary)	Lined by simple ciliated columnar epithelia
Terminal bronchioles and beginning of respiratory bronchiole	Simple ciliated columnar epithelium without mucus cells
Rest of respiratory bronchioles, alveolar duct	Non ciliated cuboidal epithelium
Alveoli	Non ciliated squamous
Alveoli of frog's lungs	Columnar ciliated epithelium

Three special types of cell are found in bronchioles epithelium :

(a) **Kultchitsky cells or argentaffin cells** : They secrete serotonin and histamine. Histamine dilates while serotonin constricts the bronchioles.

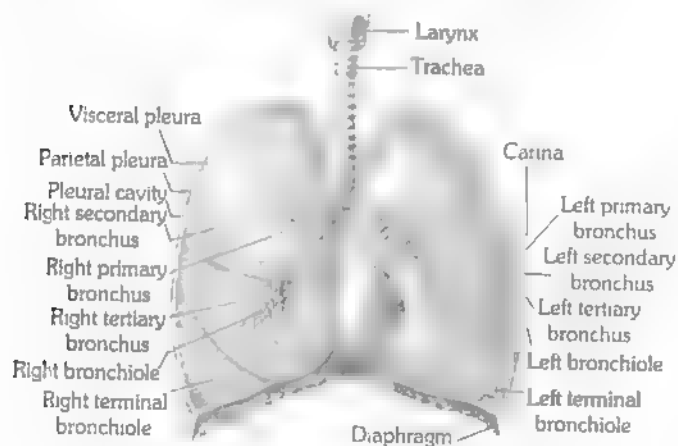
(b) **Clara cells** : They secrete a phospholipid named dipalmityl lecithin which acts as a surfactant. This surfactant prevents the collapse of bronchioles lacking cartilaginous rings. Collapsing of lungs is called atelectasis. Pottle in 1956 proved the existence of surfactant. Surfactant is formed by Clara cells only at later stage of foetal life. Some times at birth some infants are devoid of surfactant so there is great respiratory difficulty because lungs refuse to expand. In this condition death may occur. This is called respiratory distress syndrome (RDS) or hyaline membrane disease (HMD) or glassy lung disease.

(c) **Dust cells** : They are phagocytes which eat foreign particles (dust).

## Respiratory organs

In men the respiratory organ are a pair of lung. Some snakes have unpaired lungs. Respiration by lungs is called pulmonary respiration. Lungs are found in all vertebrates except fishes. In fishes such as protopterus, neoceratodus and lepidosiren air bladder is found, which is modified lung. Respiration in men and rabbit is pulmonary.

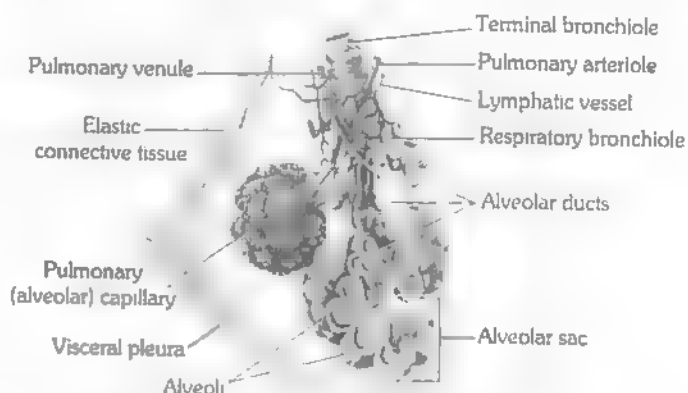
**Lungs** : Lungs lie in thoracic cavity on both sides of heart in mediastinum space. Base of lung is attached to diaphragm. Right lung is divided into 3 lobes viz. Superior, Middle, Inferior and left lung is divided into two lobes Superior and Inferior. In rabbit, the left lung is divided into two lobes left anterior and left posterior where as the right lung has four lobes anterior azygous, right anterior, right posterior and posterior azygous. Lungs of reptiles are more complex than those of amphibians. In birds lungs are supplemented by elastic air sacs which increase respiratory efficiency. The narrow superior portion of lung is termed the apex or cupula.



**Fig : 5.2-7 Branching of airway from the trachea : the bronchial tree (Anterior view)**

Each lung is enclosed in two membranes called pleura. Pleura are layers of peritoneum of thorax. Inner membrane is called the visceral pleuron. It is firmly bound to surface of lungs. The outer membrane is called parietal pleuron. It is attached to chest wall or wall of thoracic cavity. A narrow space exists between the two pleura. It is called pleural cavity. In pleural cavity a watery fluid is

found called pleural fluid. Pleural fluid is glycoprotein in nature and secreted by pleura. Pleural fluid lubricates the pleura so that they may slide over each other without friction. This fluid reduces friction between the membranes. When the lungs expand and contract in respiration. Pressure inside pleural cavity is negative – 5 mm Hg. Pleurisy is inflammation of pleura and causes collection of fluid in pleural cavity. It results in painful breathing (dyspnea). The surface of lung lying against the ribs, known as costal surface. The mediastinal (medial) surface of each lung contains a region – the hilus, through which bronchi, pulmonary blood vessels, lymphatic vessels and nerves enter and exit.



**Fig : 5.2-8 Diagram of a portion of a lobule of the lung**

## Pulmonary volumes and capacities

The apparatus commonly used to measure the volume of air exchanged during breathing and the rate of ventilation is a spirometer (spiro=breathe) or respirometer. The record is called a spirogram. There are 4 respiratory volumes and capacity.

### Respiratory volumes

(1) **Tidal volume (TV)** : Volume of air inspired or expired in relaxed or resting position – 500 ml. It consists of 150 ml of dead space volume and 350 ml of alveolar volume.

(2) **Inspiratory reserve volume (IRV)** : By taking a very deep breath, you can inspire a good deal more than 500 ml. This additional inhaled air, called IRV is about 3000 ml.

(3) **Expiratory reserve volume (ERV)** : If you inhale normally & then exhale as forcibly as possible, you should be able to push out 1100 ml. of air in addition to 500 ml. of T.V. The extra 1100 ml. is called ERV.

(4) **Residual volume (RV)** : Even after expiratory reserve volume is expelled, considerable air remains in the lung, this volume, which can not be measured by spirometry, it is called residual volume is about 1200 ml.

(5) **Dead space** : Portion of tracheobronchial tree where gaseous exchange does not occur called dead space. It is also called conductive zone. Dead space is 150 ml.

(6) **Functional residual capacity (FRC)** : It is the amount of air that remains in the lungs after a normal expiration. It is about 2300 ml.

$$\begin{aligned} \text{FRC} &= \text{ERV} + \text{RV} \\ &= 1100 + 1200 = 2300 \text{ ml} \end{aligned}$$

(7) **Vital capacity (VC)** : This is the maximum amount of air that can be expired forcefully from his lungs after first filling these with a maximum deep inspiration. It is about 4600 ml.

$$VC = IRV + TV + ERV$$

$$= 3000 + 500 + 1100 = 4600 \text{ ml.}$$

(8) **Total lung capacity (TLC)** : TLC is the sum of vital capacity (VC) and residual volume (RV). It is about 5800 ml.

$$TLC = VC + RV$$

$$= 4600 + 1200 = 5800 \text{ ml.}$$

(9) **Inspiratory capacity (IC)** : It is the total amount of air a person can inspire by maximum distension of his lungs.

$$IC = TV + IRV$$

$$= 500 + 3000 = 3500 \text{ ml.}$$

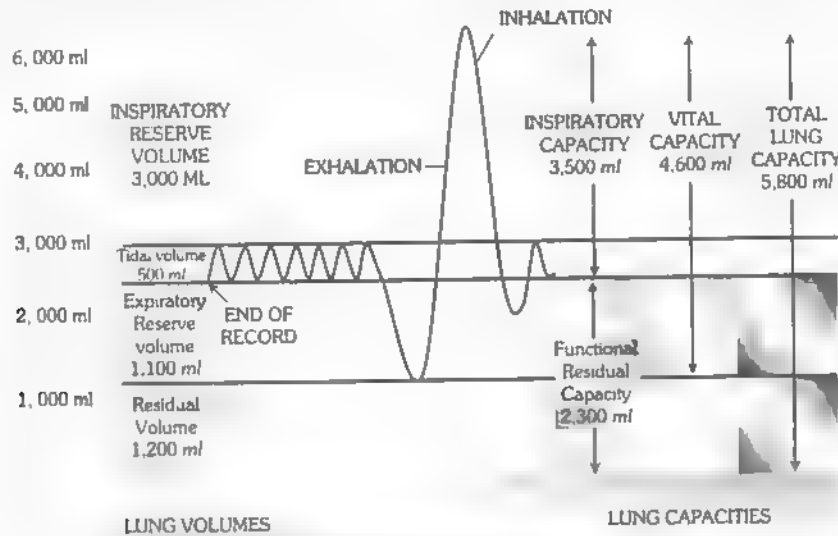


Fig : 5.2-9 Spirogram of lung volumes and capacities (average values for a healthy adult)

## Process of Respiration

The process of respiration is completed in 4 steps –

- (1) Breathing or ventilation
- (2) Exchange of gases or External respiration
- (3) Transport of gases
- (4) Cellular respiration

(1) **Breathing or ventilation** : Movement of thorax, expansion (inflation) and deflation of lungs and flow of air into the lungs and from the lungs. It is extracellular, energy consuming and physical process. Sum of inspiration and expiration is called respiratory movement. There are two steps of breathing –

(i) **Inspiration** : Intake of fresh air in lungs from outside. It is an active process. Blood pressure increases during later part of respiration. Following muscles are involved in inspiration.

(a) **Diaphragm** : Principle muscles of inspiration. It is a skeletal muscles attached to the sternum, vertebral column and ribs. It is formed by radial muscles fibres.

In relaxed condition it is dome shaped, convex towards thoracic cavity and concave towards abdominal cavity. During inspiration it contracts and become straight and descends down. This causes an increase in vertical diameter of thoracic cavity. Descent of diaphragm can explain about 75% of tidal air volume. 70% muscles fibres of diaphragm have some resistance to fatigue. Nerve which supply to diaphragm is phrenic nerve. Contribution of

diaphragm in breathing of full term pregnant lady is 0%. Most important function of diaphragm in mammals is to aid in inspiration. If diaphragm is punctured, respiration will stop and patient will die.

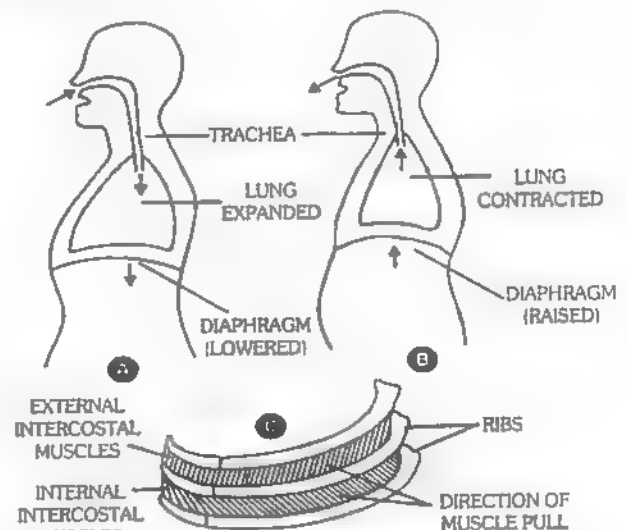


Fig : 5.2-10 Mechanism of breathing. A – Inspiration (Chest cavity enlarged) B – Expiration (Chest cavity reduced) C – Intercostal muscles

(b) **External intercostal muscles** : Gaps between the ribs are called intercostal spaces. They are filled by intercostal muscles. Intercostal muscles are of two types external intercostal muscles and internal intercostal muscles.

External intercostal muscles are related to inspiration and internal intercostal muscles are related to expiration. Here we are concerned with external intercostal muscles. External intercostal muscles start from lower border of upper rib and comes to end outer lip of upper border of lower rib. Thus direction of external intercostal muscles fibres is downward forward. Contraction of external intercostal muscles causes increase in anteroposterior diameter of thoracic cavity and transverse diameter of thoracic cavity.

This two dimensional increase in diameter (i.e. anteroposterior and transverse) of thoracic cavity is due to special arrangement of ribs. This increase in thoracic cavity is assisted by diaphragm the most important muscle of inspiration. Contraction of diaphragm causes it to flatten lowering its dome. For simplification we can assume that each rib is attached anteriorly to sternum by its anterior end and posteriorly to vertebral column by its posterior end. Note these two points carefully –

- Anterior end of rib is lower than the posterior end.
- Middle portion of rib which is called shaft lies at lower level than the two end of rib (i.e. anterior and posterior)

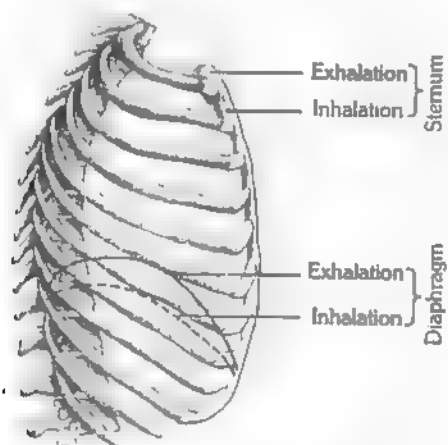
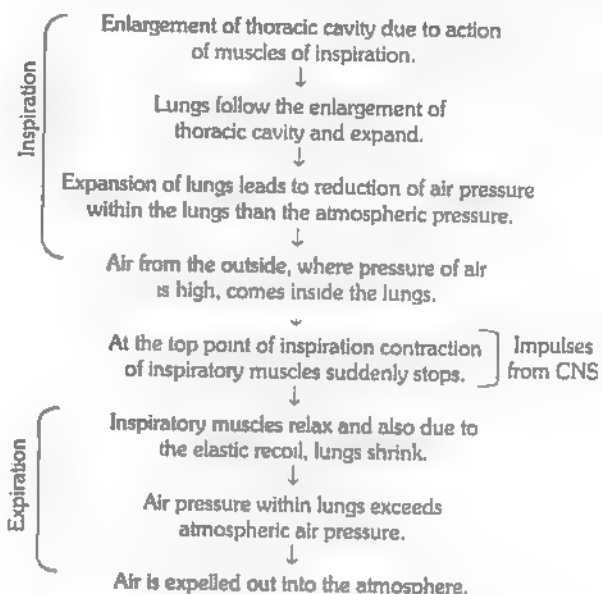


Fig : 5.2-11 Changes in size of thoracic cavity during inhalation and exhalation

(b) **Abdominal muscles** : Muscles of anterior abdominal wall. These muscles push the diaphragm up.

### (iii) Mechanism of ventilation/breathing



## (2) Exchange of gases

(i) **Exchange of gases in lungs** : It is also called external respiration. In this gaseous exchange oxygen passes from alveoli to pulmonary capillary blood and  $\text{CO}_2$ , comes to alveoli from pulmonary capillary. In order to exchange the gases have to pass through alveolocapillary membrane or respiratory membrane. Composition of alveolocapillary membrane is epithellum lining of alveolar wall, epithelial basement membrane, a thin interstitial space, capillary basement membrane and capillary endothelial membrane.

Thickness of respiratory membrane is  $0.5 \mu\text{m}$ . Respiratory membrane has a limit of gaseous exchange between alveoli and pulmonary blood. It is called diffusion capacity. Diffusion capacity is defined as volume of gas that diffuse through membrane per minute for a pressure difference of  $1 \text{ mm Hg}$ . Exchange of gases through alveolocapillary membrane is a purely physical diffusion phenomenon. No chemical reaction is involved. Diffusion of a gas depends upon pressure gradient across the membrane and solubility of gas.

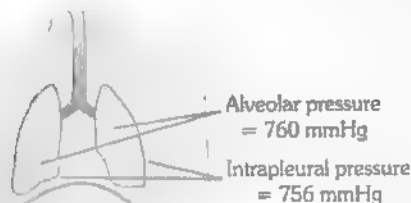
**Partial pressure** : Partial pressure of a gas is the pressure it exerts in a mixture of gases, and is equal to the total pressure of the mixture divided by percentage of that gas in the mixture. For instance, if the pressure of atmospheric air at sea level is  $760 \text{ mm}$  of mercury ( $\text{Hg}$ ) and oxygen forms  $21\%$  of the air, the partial pressure of oxygen will be  $21\%$  of  $760$ , or  $159 \text{ mm. Hg}$ . In other words, the partial pressure of a gas is proportional to its concentration in the mixture. Only about  $0.3 \text{ ml.}$  of  $\text{O}_2$  can dissolve in  $100 \text{ ml.}$  of plasma, about  $20 \text{ ml.}$  of  $\text{O}_2$  is carried by haemoglobin in  $100 \text{ ml.}$  of blood. In atmospheric air except these gases some traces of helium, argon and neon are also found

(c) **Accessory muscles of Inspiration** : These muscles normally are not called into action but in forced inspiration they come into action. Accessory muscles are scaleni, sternomastoid and alae nasi.

(ii) **Expiration** : Out flow of the air from the lungs is called expiration. When the inspiratory muscles relax, the external intercostal relax, ribs move inferiorly and as the diaphragm relaxes, its dome moves superiorly owing to its elasticity. These movements decrease vertical and anterior-posterior dimensions of thoracic cavity

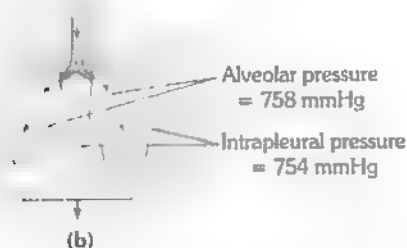
(a) **Internal intercostal muscles** : Direction of fibres is backward and downward. Action is just opposite to external intercostal muscles. These muscles by their action reduces antero-posterior and transverse diameter of thoracic cavity.

Atmospheric pressure  
= 760 mmHg



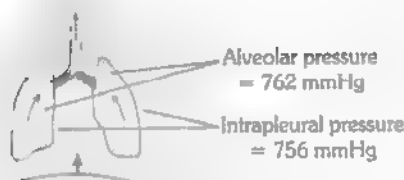
(a)

Atmospheric pressure  
= 760 mmHg



(b)

Atmospheric pressure  
= 760 mmHg



(c)

Fig : 5.2-12 Pressure changes in pulmonary ventilation ; (a) At rest (diaphragm relaxed) (b) During inhalation (diaphragm contracting) (c) During exhalation (diaphragm relaxing)

Table : 5.2-4 Partial pressures of respiratory gases in mm. Hg

Gas	Oxygen	Carbon dioxide	Nitrogen
Inspired air	158	0.3	596
Alveolar air	100-105	40	573
Venous blood	40	46	573
Arterial blood	95-100	40	573
Expired air	116	32	565
Tissue cells	20-40	45-52	—

Table : 5.2-5 Composition of three samples of air

Gas	Oxygen	Carbon dioxide	Nitrogen	Water
Inspired air	20.84%	0.04%	78.62%	0.5%
Expired air	15.70%	4.00%	74.50%	6.2%
Alveolar air	13.6%	5.3%	74.9%	6.2%
Gain/loss %	Gain 5.14%	Loss 3.96%	Gain 4.12%	Loss 5.7%

Exchange of gases in lungs can be divided into two steps –

**Uptake of  $O_2$  by blood in lung :** The  $PO_2$  (partial pressure of oxygen) of the alveolar air is higher than the  $PO_2$  of blood in alveolar capillaries. Due to a  $PO_2$  difference between air and blood, oxygen diffuses rapidly from the alveolar air into the blood of alveolar capillaries.

**Release of  $CO_2$  by the blood :** The  $PCO_2$  (partial pressure of carbon dioxide) of blood reaching the alveolar capillaries is higher than the  $PCO_2$  of alveolar air. Therefore, carbon dioxide diffuses from the blood of alveolar capillaries into the alveolar air

(ii) **Exchange of gases in tissues :** In the tissues, exchange of gases occurs between the blood and the tissue cells. This exchange occurs via tissue fluid that bathes the tissue cells. The blood reaching the tissue capillaries has  $PO_2$  higher than that in the tissue cells and  $PCO_2$  lower than that in the tissue cells. The tissue cells constantly use oxygen in oxidation that produces carbon dioxide. Therefore, they always have lower  $PO_2$  and higher  $PCO_2$  than the blood coming to them. Because of  $PO_2$  and  $PCO_2$  differences between blood and tissue cells, oxygen separates from oxyhaemoglobin and diffuses from the blood into the tissue fluid and hence into the tissue cells, and carbon dioxide diffuses from the tissue cells into the tissue fluid and thence into the blood in the tissue capillaries. Gases mostly diffuse through the tissue fluid as such, only small amounts dissolve in it.

Exchange of gases in the tissues that lowers the  $PO_2$  of the blood and raises its  $PCO_2$  is called internal respiration. The blood deoxygenated by this respiration returns to the right side of the heart that sends it to the lungs for reoxygenation.

(3) **Transport of gases :** Blood carries  $O_2$  from respiratory organs to the tissue cells for oxidation and  $CO_2$  from tissue cells to respiratory organs for elimination. Blood should be slightly alkaline to help the transport of  $O_2$  and  $CO_2$  properly.

(i) **Transport of oxygen :** Lung contains atmospheric air. From the lung  $O_2$  diffuses into the blood. The blood transport  $O_2$  from the lung to the cells. This is called oxygen transport.  $O_2$  is carried in the blood in three forms –

(a) **In physical solution :** 100 ml. oxygenated blood contains 20 ml (0.3 ml dissolved in plasma and 19.7 ml bound to Hb) of oxygen. 2-3% oxygen is transported in form of physical solution. Thus 0.3 ml to 0.6 ml  $O_2$  is in physical solution form in 100 ml of blood.

(b) **As oxyhaemoglobin ( $HbO_2$ ) :** Most of  $O_2$  is transported in the form of oxyhaemoglobin. 98.5% in the form of  $HbO_2$  and 1.5% is carried in the dissolved state in watery blood plasma.



### Oxygen-haemoglobin dissociation curve

When a graph is plotted between percent saturation of haemoglobin and oxygen tension, a curve is obtained termed as  $O_2$ -Hb dissociation curve. Oxygen-Hb dissociation curve is sigmoid shaped-or S shaped. This sigmoid shaped curve is characteristic for Hb.

Body tissue obtain oxygen from oxyhaemoglobin because of its dissociation caused by low  $O_2$  and high  $CO_2$  concentration. Under a given oxygen concentration in blood, dissociation of oxyhaemoglobin will increase if pH of blood falls. When partial pressure of  $CO_2$  rises (blood pH decreases), dissociation curve of oxyhaemoglobin at  $37^\circ C$  shift to right. Effect of high temperature and low pH (high  $PCO_2$ ) are similar.  $P_{50}$  indicates the oxygen concentration at which 50% haemoglobin of blood is saturated with  $O_2$ .

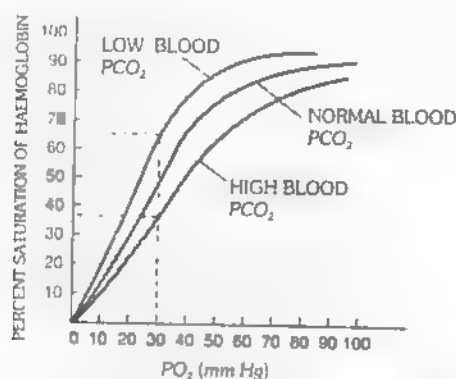


Fig : 5.2-13 Effect of  $PCO_2$  on affinity of hemoglobin for oxygen

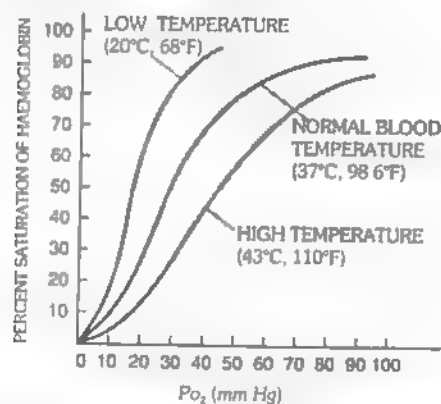


Fig : 5.2-14 Oxygen-hemoglobin dissociation curve showing the relationship between temperature and hemoglobin saturation with  $O_2$

**Bohr's effect :** Hb- $O_2$  dissociation curve shifts to right when  $CO_2$  tension in blood is high. Bohr discovered this effect in 1904. Bohr effect is the effect of  $CO_2$  on oxyhaemoglobin. Deoxygenation of oxyhaemoglobin is directly proportional to blood  $pCO_2$ . Extent of Bohr's effect depends upon the tension of  $CO_2$  in blood only.  $CO_2$  of tissue fluid and alveoli does not exert Bohr's effect. During exercise muscles need more  $O_2$  and want to remove  $CO_2$  which has high production. Because of pressure gradient

$CO_2$  moves from tissues fluid to capillary blood  $\rightarrow$  Exert Bohr's effect  $\rightarrow O_2$  release is hastened from Hb- $O_2$  i.e. Hb- $O_2$  curve shifts to right.

**Haemoglobin :** Oxygen carrier or respiratory pigment in vertebrates blood is haemoglobin. Hb molecule is made of two components haem and globin. Globin part is globulin protein which is made of four polypeptide chain, two  $\alpha$  chains (141 amino acid) and two  $\beta$  chains (146 amino acid). Thus total no. of amino acid in Hb 574. Haem is iron containing compound and belongs to the class of compound called protoporphyrins. Hb in RBC synthesized before loss of nucleus. Iron of Hb is in ferrous state ( $Fe^{++}$ ) and even after the combination with  $O_2$  it remains ferrous. One Hb molecule has 4 haem molecules. Each haem is associated without polypeptide chain. Each Hb molecule can combine with one molecule (2 atoms) of oxygen. Thus each molecule of Hb combines 4 molecules of  $O_2$ .

**Myoglobin :** It is chemically and functionally similar to Hb. It is made up of one polypeptide chain (153 amino acids) attached with one haem group.  $P_{50}$  value for myoglobin is 5 mm Hg. This indicates that myoglobin release oxygen less readily than Hb. It is found in muscles. It acts as a store house for  $O_2$ . An average man can store about 1.5 litre oxygen in myoglobin. Hb- $O_2$  dissociation curve for myoglobin is hyperbola.

(ii) **Transport of  $CO_2$  :** Transportation of  $CO_2$  by blood is much easier due to its high (20 times that of  $O_2$ ) solubility in water. Blood can carry upto 50% or 60% of  $CO_2$  by volume, but normally about 4 ml of  $CO_2$  on an average is transported from tissue to the lungs in each 100 ml of blood in man. With 5 litres of cardiac output per minute, the blood thus transports about 200 to 220 ml of  $CO_2$  each minute. Obviously, this is the rate at which  $CO_2$  is produced and released into tissue fluids by cells, and at which it diffuses out into alveolar air from pulmonary arterial blood. The blood transports this  $CO_2$  in three ways

(a) **In dissolved state :** Deoxygenated ( $PCO_2$  is 45 to 46 mm Hg) and oxygenated ( $PCO_2$  is 40 mm Hg) bloods respectively carry about 2.7 and 2.4 ml of  $CO_2$  per 100 ml of blood in dissolved state in plasma (= in solution with plasma). Thus, about 0.3 (2.7 minus 2.4) ml of  $CO_2$  is transported by each 100 ml of blood in dissolved state in plasma. This is about 7% of all the  $CO_2$  transported by blood from tissues to the lungs

(b) **In the form of bicarbonate ions :** Most of the  $CO_2$  that dissolved in blood plasma reacts with water, forming carbonic acid –  $CO_2 + H_2O = H_2CO_3$  (carbonic acid)

This reaction is very slow in plasma, but occurs very rapidly inside RBCs, because an enzyme, carbonic anhydrase, present in RBCs, accelerates its rate about 5000 times. That is why, about 70% of the  $CO_2$  (about 2.5 ml per 100 ml of blood), received by blood from the tissues, immediately enters into RBCs and hydrated to carbonic acid. Almost as rapidly as formed, all carbonic acid of RBCs dissociates into hydrogen and bicarbonate ions ( $H^+$  and  $HCO_3^-$ ). The hydrogen ions mostly combine with haemoglobin for

keeping the pH of blood, (7.4) in steady state, because haemoglobin is a powerful acid base buffer. Being quite diffusible, the bicarbonate ions, on the other hand, diffuse from RBCs into the plasma. To maintain electrostatic neutrality of plasma, many chloride ions, in turn, diffuse from plasma into the RBCs. Obviously, the chloride contents of RBCs increase when oxygenated blood becomes deoxygenated. This is termed "chloride or Hamburger shift".

**Sequence of events :** From tissues  $\text{CO}_2$  enters in plasma  $\rightarrow$  a small fraction of  $\text{CO}_2$  is dissolved in plasma  $\rightarrow$  rest of  $\text{CO}_2$  enters into the RBC  $\rightarrow$  within RBC  $\text{CO}_2$  combines with  $\text{H}_2\text{O}$  in presence of enzyme carbonic anhydrase and forms  $\text{H}_2\text{CO}_3 \rightarrow \text{H}_2\text{CO}_3$  splits into  $\text{H}^+$  and  $\text{HCO}_3^- \rightarrow$  most of the  $\text{HCO}_3^-$  comes out of RBC and enters in plasma and form  $\text{NaHCO}_3$ , small fraction stays back within the RBC to form  $\text{KHCO}_3$  and  $\text{H}^+$  combine with  $\text{Hb}$  to form reduced haemoglobin  $\text{H.Hb}$

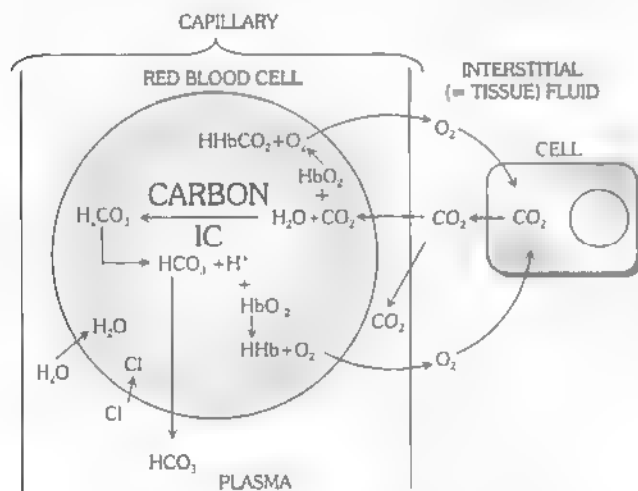


Fig : 5.2-15 Transportation of  $\text{CO}_2$  by blood

(c) **In the form of carbamino compounds :** In addition to reacting with water,  $\text{CO}_2$  also directly and reversibly reacts with haemoglobin, loosely binding with it and forming an unstable compound, called carbaminohaemoglobin ( $\text{CO}_2\text{HHb}$ ). It also similarly forms loose bonds with some plasma proteins. It is estimated that about 23% of the  $\text{CO}_2$  (1 ml per 100 ml of blood), collected from cells through tissue fluids, is transported by blood in this form.

Table : 5.2-6 Transformation of  $\text{CO}_2$  in various forms

Transformation forms of $\text{CO}_2$	Transported quantity
$\text{CO}_2$	7% (0.3 ml/100ml of blood)
$\text{HHbCO}_2$	23% (1ml/100 ml of blood)
$\text{HCO}_3^-$	70% (2.5 ml/100 ml of blood)

**Haldane effect and  $\text{CO}_2$  diffusion into the alveoli :** Whereas the Bohr effect promotes  $\text{O}_2$  transport, the Haldane effect is important in promoting  $\text{CO}_2$  transport. The Haldane effect results

from the simple fact that oxyhaemoglobin behaves as a strong acid. This in turn, displaces  $\text{CO}_2$  from the blood in two ways.

(1) Due to its increased acidity, the haemoglobin loses its capacity to combine with  $\text{CO}_2$ . Hence all carbamino haemoglobin dissociates to release its  $\text{CO}_2$ .

(2) Secondly, the highly acidic oxyhaemoglobin releases an excess of  $\text{H}^+$  which bind with bicarbonate ions ( $\text{HCO}_3^-$ ), forming carbonic acid. The latter soon dissociates into  $\text{H}_2\text{O}$  and  $\text{CO}_2$ . This  $\text{CO}_2$  diffuses into the alveoli.

Thus, in the lung, the haldane effect, increases release of  $\text{CO}_2$  because of  $\text{O}_2$  uptake by haemoglobin. In the tissues a reverse process occurs. The Haldane effect increases  $\text{CO}_2$  uptake because of removal of  $\text{O}_2$  from haemoglobin.

### Control of breathing

Respiratory rhythm is controlled by nervous system. Inspiratory and expiratory centres are jointly called rhythmicity centres. Inspiratory centre is dominant over expiratory centre. When pneumotaxic is stimulated respiration rate increases inspiration as well as expiration is shortened. Respiratory movements are under control of *medulla oblongata*.

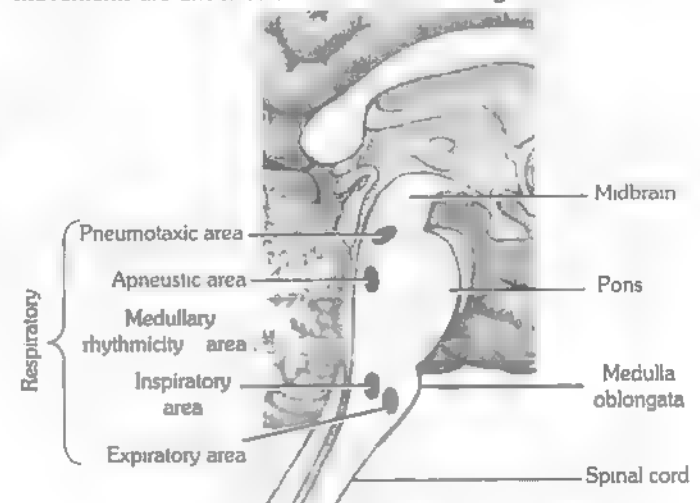
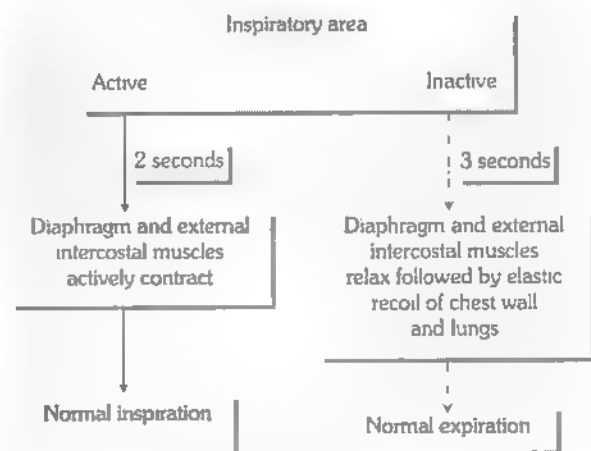
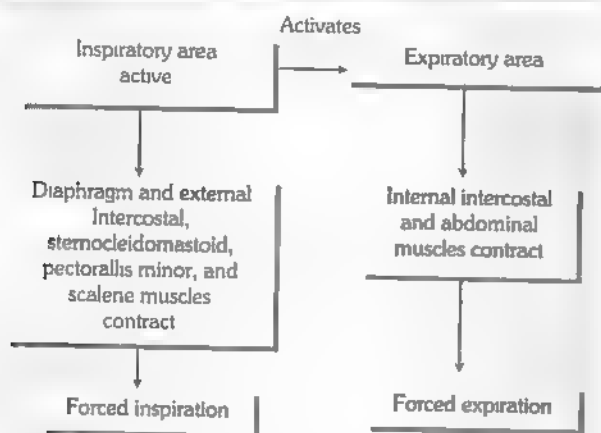


Fig : 5.2-16 Sagittal section of brain stem



(a) During normal quiet breathing



(b) During labored breathing

**Table : 5.2-7 For the control of respiration following respiratory centres are found in hind brain**

Type of centre	Location	Function
Inspiratory centre	Medulla oblongata	Inspiration (2 second active condition)
Expiratory centre	Medulla oblongata	Expiration (3 second inactive condition)
Apneustic centre	Pons	Slow and deep inspiration
Pneumotaxic centre	Pons	Control other centres and produce normal quite breathing
Gasping centre	Pons	Sudden and shallow respiration

(1) **Chemical control** : This includes  $\text{CO}_2$ ,  $\text{O}_2$  and  $\text{H}^+$  conc. of blood. For detection of concentration of  $\text{O}_2$ ,  $\text{CO}_2$  and  $\text{H}^+$  ions in blood two types of receptors are found. These receptors are called chemoreceptor.

(i) **Peripheral chemoreceptor** : These include two sets – Carotid body is present in the wall of the left and the right common carotid arteries and aortic bodies is present in the arch of aorta. They are placed in the vascular endothelium and come in contact with the blood. When  $\text{PO}_2$  decreases or increases in arterial blood, these receptors are stimulated and send impulses to respiratory centre to respectively increases or decreases the rate intensity of inspiratory signals.

(ii) **Central chemoreceptors** : These are present on ventral surface of medulla. Cells of these centres are bathed in brain tissue fluid. They are in close vicinity of CSF. In brain tissue fluid as well as in CSF the  $\text{CO}_2$  is converted into



$\text{H}^+$  ions stimulate the central chemoreceptor (C.C) cell  $\rightarrow$  stimulation from C.C goes to respiratory centre  $\rightarrow$  Respiration stimulate.

## (2) Effect of different gases

(i) **Effect of  $\text{CO}_2$**  : Rise in tension of arterial  $\text{CO}_2$  or alveolar  $\text{CO}_2$  causes stimulation of respiration. Both the rate and depth of respiration increased. This leads to washing out of  $\text{CO}_2$  from body.

(ii) **Effect of  $\text{O}_2$**  : Fall of  $\text{O}_2$  concentration in inspired air causes stimulation of peripheral chemoreceptors. Neural impulse arises from peripheral chemoreceptors. These impulses go to respiratory centre and cause respiratory stimulation.

## Respiration in frog

Frog is an amphibious animal i.e. they are live in water as well as on land hence according to their adaptations they posses different modes of respiration, which are as follows –

(1) **Cutaneous respiration** : By the skin. Under water, during hibernation frog respire by only skin. On land cutaneous respiration continues as usual. Thus cutaneous respiration take place always. By cutaneous respiration frog fulfill its 30% need of oxygen.

(2) **Buccopharyngeal respiration** : Like the skin, the mucosa of buccopharyngeal cavity in frog is also ideally adapted for gaseous exchange. Hence, while quietly floating upon water surface, and even when resting upon land, frogs respire by their buccopharyngeal cavity also. During this process, the mouth, gullet and glottis remain closed, but nares remain open.

(3) **Pulmonary respiration** : In frog, pulmonary respiration accounts for about 65% of the total  $\text{O}_2$ -intake. It particularly occurs when frogs lead an active life during rains and spring; either hopping upon land in search of food, or actively breeding in water.

## Important concept of respiration

(1) **Respiratory quotient (R.Q.)** : Respiratory quotient is the ratio of carbon dioxide output to oxygen usage during respiration. It is measured by Ganong's respirometer

$$\text{R.Q.} = \frac{\text{Volume of } \text{CO}_2 \text{ formed}}{\text{Volume of } \text{O}_2 \text{ utilized}}$$

**Table : 5.2-8**

High RQ	Low RQ
Due to fat deposition	When $\text{CO}_2$ is fixed
Due to fever	When $\text{CO}_2$ retain in tissue
Due to muscle exercise	In hibernating mammals
During glycolysis	Due to acidosis
In low $\text{O}_2$ environment	Due to alkalosis
Due to oxidation of pyruvic acid.	Due to diabetes
	In starvation
	During gluconeogenesis
	During glyconeogenesis

The volume of RQ depends upon the type of fuel substance being utilized for energy production.

**Table : 5.2-9 RQ of various substrates**

Respiratory substrate	Respiratory quotient
Carbohydrate	1.00
Proteins	0.5 – 0.9 Slightly less than 1 (0.9)
Fats	0.7
Organic acid	1.33

In an organism utilizing carbohydrates as source of energy anaerobically, the RQ is likely to be infinity. When carbohydrates are substrates for respiration, it is called 'floating respiration'. Diabetic patient shows low R.Q. due to increased dissimilation of fats and the decreased dissimilation of carbohydrate.

(2) **Effect of CO** : Carbon monoxide is a poisonous gas. Hb has maximum affinity for CO. Carbon monoxide binds with haemoglobin at the same place where  $O_2$  binds, but about 250 times more readily than  $O_2$ . Hence, it readily displaces  $O_2$  from haemoglobin and even a 0.4 mm Hg partial pressure of CO in alveolar air is enough to occupy about half of the haemoglobin of pulmonary blood rendering it useless for  $O_2$  transport. A CO pressure of about 0.7 mm Hg (concentration of about 1%) in alveolar air can be lethal. That is why, the atmosphere of industrial areas, being loaded with chimney smoke, is regarded harmful to health. It forms carboxyhaemoglobin with Hb which is most stable. Sudden deep inspiration is due to either increase in concentration of  $CO_2$  or decrease in concentration of  $O_2$ . Forced deep breathing for a few minutes by a person sitting at rest may be followed by a temporary cessation of breathing. This is influenced by too much  $O_2$  and least  $CO_2$  in blood.

(3) **Regulation at high altitudes** : At high altitudes, the composition of air remains almost the same as at sea-level, but the density (barometric pressure) of air gradually decreases. While ascending up a mountain, one inspires thin air, getting less oxygen. Less  $O_2$  level in the blood results in hypoxia. The chemoreceptor stimulatory mechanism progressively increases the rate of ventilation. Ventilation ordinarily does not increase significantly until one has ascended to about 2500 metres, because the  $P_{CO_2}$  and pH remain almost normal.

#### Disorders of Respiratory system

(i) **Hypoxia** : Hypoxia is a condition of oxygen shortage in the tissues. It is of two types :

(a) **Artificial Hypoxia** : It results from shortage of oxygen in the air as at high (over 2400 m.) altitudes. It causes mountain sickness characterised by breathlessness, headache, dizziness, nausea, vomiting, mental fatigue and bluish tinge on the skin and mucous membranes.

(b) **Anaemic Hypoxia** : It results from the reduced oxygen-carrying capacity of the blood due to anaemia (decreased haemoglobin content in blood) or carbon monoxide poisoning (some haemoglobin occupied by CO). In both cases, less haemoglobin is available for carrying  $O_2$ .

(i) **Asphyxia (Suffocation)** : The  $O_2$  content of blood falls and the  $CO_2$  content rises and paralyses the respiratory centre. Breathing stops and death occurs.

(ii) **Bad cold** : Disease-causing microbes present in the air attack respiratory tract, producing inflammation of the mucous membrane and caused increased secretion :

(a) **Rhinitis** in the nasal chambers.

(b) **Sinusitis** in the sinuses.

(c) **Pharyngitis** in the pharynx, often called sore throat, and is usually accompanied by tonsillitis (enlargement of tonsils).

(d) **Laryngitis** in the larynx, causing hoarse voice and difficulty in speaking.

(e) **Bronchitis** in the bronchioles.

(iv) **Emphysema** : The air-pollutants that cause chronic bronchitis, may breakdown the alveoli of the lungs, reducing the surface area for gas exchange. The victim becomes permanently short of breath.

(v) **Bronchial asthma** : It is an allergic attack of breathlessness associated with bronchial obstruction or spasm of smooth muscle (contraction), characterized by coughing difficult breathing and wheezing patient has trouble exhaling.

(vi) **Bronchitis** : It is caused by the permanent swelling in bronchi. As a result of bronchitis cough is caused and thick mucus with pus cells is spitted out. Dyspnea and fever develops. Dyspnea means hunger of air or deficiency of oxygen in the blood or development of hypercapnia i.e., increase of  $CO_2$  concentration in blood. This disease is accelerated by fatigue, malnutrition, cold etc. the patient experiences difficulty in breathing. Here hypertrophy and hyperplasia of bronchi takes place.

(vii) **Pneumonia** : Oxygen has difficulty diffusing through the inflamed alveoli and the blood  $PO_2$  may be drastically reduced. Blood  $PCO_2$  usually remain normal because  $CO_2$  diffuses through the alveoli more easily than  $O_2$ . In chronic patients of common cold and influenza, the lining epithelium of bronchi and lungs is inflamed. This disease is caused by streptococcus pneumoniae, other bacteria, fungi, protozoans, viruses and the patient feels difficulty in breathing. Its prominent symptoms are trembling, pain in chest, fever, cough delirium etc. This disease is prevalent in either children or elderly persons in old age.

(viii) **Lung cancer** : It is believed that by excess smoking, lung cancer (carcinoma of lungs) is caused. The tissue increases limitlessly, which is called malignancy. This disease is fatal. The frequency of occurrence of this disease in smokers is 20% more. Malignancy of tissues (neoplasia) causes pressure on the cells of other tissues and destroys them. The blood capillaries are ruptured, blood starts flowing and death is caused by excessive bleeding.

(ix) **Tuberculosis** : This disease is also called T.B. and was considered fatal, but these days its full cure is possible. Thus, disease is called curable, these days. It is caused by bacteria *Mycobacterium tuberculosis*. These bacteria settle in lungs at different places and convert normal tissue into fibrous tissue. Since the respiratory surface is decreased, the difficulty in breathing is also experienced. If the patients start taking medical advice and the medicines right from the initial stage regularly, the patients can be fully cured of the disease. Now a days a new therapy DOT (Direct observed treatment) is used for tuberculosis treatment, recently launched by Indian Government. Many other drugs like rifampin and isoniazid are successful for the treatment of tuberculosis. Tuberculosis bacteria are spread by inhalation and exhalation.

(x) **Coryza** : Common cold, due to rhinoviruses in adult.

(xi) **Influenza** : Flu.

(5) **Occupational lung disease** : It is caused because of the exposure of potentially harmful substances. Such as gas, fumes or dusts, present in the environment where a person works. Silicosis and asbestosis are the common examples, which occur due to chronic exposure of silica and asbestos dust in the mining industry. It is characterised by fibrosis (proliferation of fibrous connective tissue) of upper part of lung, causing inflammation.

(i) **Prevention and cure** : Almost all the occupational lung diseases, express symptoms after chronic exposure, i.e., 10-15 years or even more. Not only this, diseases like silicosis and asbestosis are incurable. Hence, the person likely to be exposed to such irritants should adopt all possible preventive measures. These measures include .

(a) Minimizing the exposure of harmful dust at the work place.

(b) Workers should be well informed about the harm of the exposure to such dusts

(c) Use of protective gears and clothing by the workers at the work place.

(d) Regular health check up.

(e) Holiday from duty at short intervals for the workers in such areas

(f) The patient may be provided with symptomatic treatment, like bronchodilators and antibiotics, to remove underlying secondary infection.

#### (6) Special respiratory movements

##### Cough

(1) It is reflex action stimulation takes place from trachea and lungs

(2) Centre is medulla oblongata.

(3) Cough is a forcible expiration usually produced after a prolonged inspiration

(4, When some food particle enters the windpipe instead of oesophagus, it is expelled by a process of coughing.

(5) Air exploded through the mouth.

##### Sneezing

(1) Reflex action stimulated by olfactory epithelium of nasal chamber.

(2) Sneezing is a forcible expiration, air explodes out through nose and mouth.

##### Hiccuping

(1) Hiccuping is a noisy inspiration caused by muscular spasm of diaphragm at irregular intervals.

(2) Noise is due to sudden sucking of air through vocal cords.

(3) Stimulation of hiccuping is usually irritation of the sensory nerve endings of the digestive tract

**Yawning** : Yawning is a prolonged inspiration. Low oxygen tension in the blood causes yawning.

**Table : 5.2-10 Terminology**

Apnea	Absence of breathing
Eupnea	Normal breathing
Hypopnea	Decreased breathing rate
Hyperpnea	Increased breathing rate
Dyspnea	Painful breathing
Orthopnea	Inability to breathe in a horizontal position
Acapnoea	Absence of CO <sub>2</sub> in blood
Hypocapnea	Deficiency of CO <sub>2</sub> in blood
Hypercapnea	Excess of CO <sub>2</sub> in blood
Hypoxaemia	Lack of O <sub>2</sub> in arterial blood
Anoxia	Absence of O <sub>2</sub> in tissues
Hypoxia	Lack of O <sub>2</sub> in tissues
Tachypnea	Rapid breathing

**Table : 5.2-11 Respiratory pigments**

Name of pigment	Colour (oxidised)	Metal	Place	Example
Haemoglobin	Red	Fe	RBC	Chordata (Vertebrate)
Haemocyanin	Blue	Cu	Plasma	Mollusca and arthropoda
Chlorocruorin	Green	Fe	Plasma	Annelida, sabella, serpulids
Haemoerythrin	Red	Fe	Corpuscle	Annelida, Sipunculoid ea, lingula
Vanadium	Green	Va	Vanadocytes In Plasma	Urochordata
Echinochrome	Red	Fe	Coelomic fluid	Echinodermata
Pinnoglobin	Brown	Mn	Coelomic fluid	Pinna
Moledin	Brown	Mo	Coelomic fluid	Holothuria
Haemoglobin	Red	Fe	Plasma	Earthworm, nereis, arenicola, chironomas insect, planorbis
Erythrocrunin	Red	Fe		Leech

## Tips & Tricks

- ✎ Protoplasmic respiration refers to the respiration of proteins.
- ✎ Polarography is employed to measure the concentration of oxygen in fluid
- ✎ Accumulation of blood in pleural cavity is called haemothorax.
- ✎ Accumulation of water is called hydrothorax.
- ✎ Accumulation of pus is called pyothorax.
- ✎ Accumulation of air is called pneumothorax.
- ✎ Besides lungs, the term alveolus is associated with bony socket for tooth, and in mammary glands also.
- ✎ In general, a man respires about 16 - 18 time in a minute.
- ✎ A new born child respires 32/min.
- ✎ A five year old child respires 26/min.
- ✎ A fifty year old man respires 18/min.
- ✎ No respiratory pigment in cockroach.
- ✎ Smaller the animal higher the respiratory rate.
- ✎ Rate of respiration is directly proportional to concentration of  $\text{CO}_2$  in blood.
- ✎ Metabolic rate of body is directly proportional to the total pulmonary ventilation.
- ✎ Intra aortic balloon pump is inflated by helium.
- ✎ In pregnant woman diaphragm does not take part in breathing.
- ✎ In frog larynx and trachea are fused together to form laryngo tracheal chamber.
- ✎ Lungs of frog acts as positive pressure pump, while lungs of mammal acts as negative pressure pump.
- ✎ Disorder such as asthma and emphysema can greatly reduce the expiratory reserve volume.
- ✎ At about 4 weeks foetal development, the respiratory system begins as an outgrowth of endoderm of foregut, known as laryngotracheal bud.
- ✎ After 6 months, formation of alveoli of lungs.
- ✎ The pneumotoxic and the apneustic area in pons.
- ✎ If arterial  $\text{PCO}_2$  is more than 40 mm Hg, the condition is called as hypercapnia.
- ✎ If arterial  $\text{PCO}_2$  is lower than 40 mm Hg, the condition is called as hypocapnia.

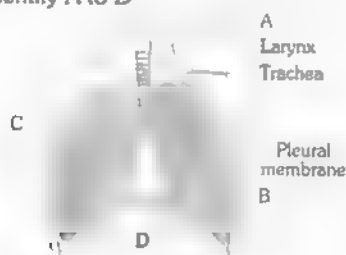
- ✎ Double Bohr effect refers to the situation in the placenta where the Bohr effect is operative in both the maternal and foetal circulation.
- ✎ Ozone, a strong oxidizing agent, oxidises iron of Hb and forms a stable compound methaemoglobin which can not release  $\text{O}_2$ .
- ✎ Air bladder perform the functions of hydrostatic organ, sound production, audition and respiration.
- ✎ Foetal Hb takes  $\text{O}_2$  from mother haemoglobin across the placenta due to double Bohr effect.
- ✎ In embryos of mammals, respiration takes place by chorion.
- ✎ In lungs of birds capillaries are present in place of alveoli.
- ✎ Exchange of  $\text{O}_2$  takes place twice in lungs of birds. It is called double respiration.
- ✎ Aquatic salamander is lungless amphibians.
- ✎ In snakes, only right lung is functional, left lung is reduced.
- ✎ In penguins double trachea is present
- ✎ In pregnant females most part during breathing is played by intercostal muscles.
- ✎ Whales and other aquatic mammals suffocate on land because their intercostal muscles can not expand their chest due to their massive body weight.
- ✎ In monkeys, kangaroo and other jumping animals, intercostal muscles play important role in breathing.
- ✎ **Smoke inhalation injury** – Has three components that occur in sequence
  - Inhibition of  $\text{O}_2$  delivery and utilization.
  - Upper airway injury from heat.
  - Lung damage from acid and aldehyde in smoke.
- ✎ **SARS – Severe Acute Respiratory Syndrome** –
  - SARS is a highly infectious disease caused by corona virus
  - Corona virus is a RNA virus, its genome was sequenced within 15 days.
  - The origin of SARS is from South China, this disease spread to Hongkong
  - Bird sellers and persons in contact with birds suffer from SARS
  - Symptoms of infections are flue like. Fever occurs with dry cough. There is difficulty in breathing. Fluid fills in lungs and death occurs within one week of infection from respiratory failure.
  - Rate of death was initially 4% but now death rate has increased to 10%
  - Line of treatment is quarnatine and ribovinin durgs.
  - The causative agent of SARS was identified by Dr. Malik Peiris of Microbiology Department of Hongkong University.

# **Ordinary Thinking**

## **Objective Questions**

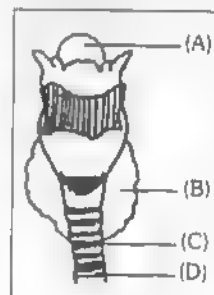
### **Respiratory organs**

- Which one of the following has the smallest diameter  
[NCERT; Kerala CET 2003]  
(a) Right primary bronchus (b) Left primary bronchus  
(c) Trachea (d) Respiratory bronchiole
- Oxygen in lungs ultimately reaches in [MP PMT 1998]  
(a) Alveoli (b) Trachea  
(c) Bronchus (d) Bronchioles
- Respiratory pigment in cockroach is  
[RPMT 1999; Odisha JEE 2010]  
(a) Haemozoin (b) Haemocyanin  
(c) Haemoglobin (d) Absent
- See the following diagrammatic view of human respiratory system. Identify A to D [NCERT]



- (a) A - Soundbox, B - Alveoli, C - Bronchioles, D - Diaphragm  
(b) A - Soundbox, B - Alveoli, C - Bronchus, D - Diaphragm  
(c) A - Epiglottis, B - Alveoli, C - Bronchioles, D - Diaphragm  
(d) A - Epiglottis, B - Alveoli, C - Bronchus, D - Diaphragm
- In man and mammals, air passes from outside into the lungs through [NCERT; BHU 1999; CPMT 2000]  
(a) Nasal cavity, larynx, pharynx, trachea bronchi, alveoli  
(b) Nasal cavity, larynx, pharynx, trachea, bronchioles, alveoli  
(c) Nasal cavity, pharynx, larynx, trachea, bronchioles, bronchi, alveoli  
(d) Nasal cavity, pharynx, larynx, trachea, bronchi, bronchioles, alveoli
- Which of the following is a respiratory organ of scorpion [CBSE PMT 2002; BVP 2002]  
(a) Gill (b) Lung  
(c) Ctenidia (d) Book lung
- During forced expiration, actively contracting muscles include the [CBSE PMT 2001]  
(a) Diaphragm  
(b) External intercostals  
(c) Abdominal muscles  
(d) Diaphragm and intestinal muscle
- In which part gaseous exchange take place in rabbit [NCERT; RPMT 2001]  
(a) Trachea and alveolar duct  
(b) Trachea and bronchi  
(c) Alveolar duct and alveoli  
(d) Alveoli and tissues

- Difference between trachea and fallopian tube is [CPMT 1995]  
(a) Trachea is related with respiration where as fallopian tube is related with reproduction  
(b) Trachea is related with respiration and fallopian tube with excretion  
(c) Trachea is related with reproduction and fallopian tube with excretion  
(d) Trachea is related with reproduction and fallopian tube with respiration
- Vocal cords are situated at [MP PMT 1995, 99]  
(a) Pharynx (b) Larynx  
(c) Glottis (d) Bronchial tube
- Carbon dioxide is transported via blood to lungs mostly [CBSE PMT 1995; Odisha JEE 2008]  
(a) As carbaminohaemoglobin and as carbonic acid  
(b) In the form of carbonic acid only  
(c) In combination with haemoglobin only  
(d) Dissolved in blood plasma
- Which is a common passage in swallowing food and breathing [CPMT 1993; MP PMT 1995]  
(a) Larynx (b) Gullet  
(c) Glottis (d) Pharynx
- The diagram represents the human larynx. Choose the correct combination of labelling from the options given [Kerala PMT 2008]



- (a) A - Larynx, B - Parathyroid, C - Tracheal cartilage, D - Trachea  
(b) A - Naso Larynx, B - Thyroid, C - Tracheal cartilage, D - Trachea  
(c) A - Trachea, B - Thyroid, C - Bronchiole, D - Tracheal cartilage  
(d) A - Epiglottis, B - Thyroid, C - Tracheal cartilage, D - Trachea  
(e) A - Epiglottis, B - Parathyroid, C - Trachea, D - Tracheal cartilage
- In human beings, lungs are divided into  
(a) 3 right and 2 left lobes (b) 2 right and 3 left lobes  
(c) 2 right and 2 left lobes (d) None of these
- Similarity between the trachea of cockroach and rabbit is that [AFMC 1994; CPMT 1995]  
(a) Both are paired and branched  
(b) Ciliated epithelium is present in both  
(c) Walls of both can not be deformed  
(d) In both head originates from pharynx
- In rabbit alveolar ducts originate from  
(a) Bronchi (b) Trachea  
(c) Bronchiole (d) Respiratory bronchiole

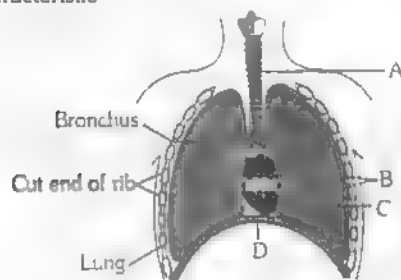
17. The cartilage present in the larynx of rabbit are [BHU 2002]  
 (a) Thyroid, cricoid, arytenoid  
 (b) Thyroid, cricoid, epiglottis  
 (c) Thyroid, cricoid, ethmoid  
 (d) Thyroid, cricoid, palatine

18. In which of the following animals Hb (Haemoglobin) is found dissolved in plasma [CPMT 1998; DPMT 2007]

Or

In which of the following animals, respiration occurs without any respiratory organ [CPMT 2003]

- (a) *Planaria* (b) Cockroach  
 (c) *Sepla* (d) Earthworm
19. The exchange of gases ( $O_2$  and  $CO_2$ ) in a mammal takes place in [NCERT; CPMT 1992]  
 (a) Trachea (b) Bronchi  
 (c) Bronchiole (d) Alveoli
20. The figure shows a diagrammatic view of human respiratory system with labels A, B, C and D. Select the option which gives correct identification and main function and/or characteristic



[NEET 2013]

- (a) D – Lower end of lungs – diaphragm pulls it down during inspiration  
 (b) A – Trachea – long tube supported by complete cartilaginous rings for conducting inspired air  
 (c) B – Pleural membrane – surround ribs on both sides to provide cushion against rubbing  
 (d) C – Alveoli – thin walled vascular bag like structures for exchange of gases
21. Larynx is found in [MP PMT 1992]  
 (a) Both frog and rabbit (b) Neither frog nor rabbit  
 (c) Frog but not in rabbit (d) Rabbit but not in frog
22. The long trachea of rabbit contains [CPMT 1992]  
 (a) Buccal cord  
 (b) Thyroid  
 (c) Complete tracheal cartilage  
 (d) Incomplete tracheal cartilage
23. The right lung of rabbit has four lobes. They are [CPMT 1992; MP PMT 1995]  
 (a) Anterior lobe, anterior azygous, posterior lobe and right anterior  
 (b) Posterior lobe, posterior and anterior azygous, right anterior and right posterior  
 (c) Anterior azygous, right anterior, right posterior and posterior azygous lobe  
 (d) Anterior lobe, anterior azygous, right anterior and posterior azygous lobe
24. There is a membrane covering the lungs, called [MP PMT 1994; KCET 1999; MH CET 2000; Pb. PMT 2004; AFMC 2005]  
 (a) Peritonium (b) Pleura  
 (c) Pericardium (d) Duramater
25. In rabbit the lungs are lodged in [CPMT 1992]  
 (a) Thoracic cavity (b) Abdominal cavity  
 (c) Pleural cavity (d) Pericardial cavity
26. The most important function of diaphragm of the mammals is  
 (a) To divide the body cavity into compartment  
 (b) To protect lungs  
 (c) To aid in respiration  
 (d) To aid in ventilation
27. The pigment haemocyanin is found in [BVP 2000; AIIMS 2000; CBSE PMT 2002; MHCET 2002]  
 (a) Chordata (b) Annelida  
 (c) Mollusca (d) Echinodermata
28. Lung ventilation movements are due to [Odisha JEE 2005]  
 (a) Costal muscles and diaphragm  
 (b) Costal muscles  
 (c) Diaphragm  
 (d) Wall of the lungs
29. What is true about haemoglobin [AIEEE Pharmacy 2006]  
 (a) It is a dipeptide and present in red blood corpuscles in blood worm  
 (b) It is present in the dissolved state in blood plasma in earthworm  
 (c) It is a dipeptide in mammals and localised in red blood corpuscles  
 (d) It is present in dissolved state in blood plasma in scorpions
30. The structure which prevents the entry of food into respiratory tract is  
 (a) Pharynx (b) Larynx  
 (c) Glottis (d) Epiglottis
31. In which animal, diaphragm has no role in respiration [MH CET 2003]  
 (a) Frog (b) Rat  
 (c) Camel (d) Rabbit
32. Thyroid is a cartilaginous plate in [CPMT 1992, 93]  
 (a) Skull of rabbit (b) Larynx of rabbit  
 (c) Vertebrae of rabbit (d) Sternum of rabbit
33. The diaphragm in rabbit is a [J & K CET 2005]  
 (a) Gap between the incisor and premolar teeth  
 (b) Membrane which surrounds and protects the brain  
 (c) Membrane which lies between the external auditory meatus and tympanic cavity of the ear  
 (d) Partition of muscular septum separating the thoracic cavity from abdominal cavity

### Pulmonary volumes and capacities

1. What is vital capacity of our lungs [CBSE PMT 2008]  
 (a) Inspiratory reserve volume plus expiratory reserve volume  
 (b) Total lung capacity minus residual volume  
 (c) Inspiratory reserve volume plus tidal volume  
 (d) Total lung capacity minus expiratory reserve volume
2. The vital capacity of the lung signifies the volume of air  
 (a) Breathed in during normal inspiration  
 (b) Breathed out with forcible expiration  
 (c) Breathed in with forcible inspiration  
 (d) With deep inspiration and forcible expiration



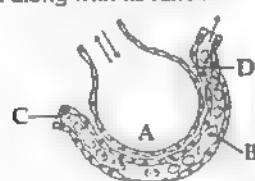
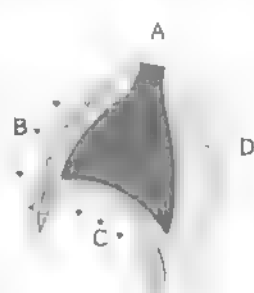
3. Arrange the following in the order of increasing volume  
 (1) Tidal volume  
 (2) Residual volume  
 (3) Expiratory reserve volume  
 (4) Vital capacity [NCERT; AIIMS 2007]  
 (a)  $1 < 2 < 3 < 4$  (b)  $1 < 3 < 2 < 4$   
 (c)  $1 < 4 < 3 < 2$  (d)  $1 < 4 < 2 < 3$
4. The volume of air present in the lungs after forceful expiration is called as [KCET 2006]  
 (a) Tidal volume (b) Residual air  
 (c) Complementary air (d) None
5. The largest quantity of air that can be expired after a maximum inspiratory effort is [NCERT; CPMT 1999; Pb. PMT 1999; CPMT 2004; MP PMT 2007; Odisha JEE 2011]  
 (a) Residual volume (b) Tidal volume  
 (c) Vital capacity of lung (d) Lung volume
6. The volume of air which remains in the conducting airways and is not available for gas exchange is called [J & K CET 2012]  
 (a) Vital capacity  
 (b) Functional residual capacity  
 (c) Forced expiratory volume  
 (d) Anatomic dead space
7. How much amount of volume of air is in lungs FRC [GUJCET 2015]  
 (a) 1500 ml to 1600 ml (b) 2100 ml to 2500 ml  
 (c) 2500 ml to 3000 ml (d) 1600 ml to 2100 ml
8. The enzyme essential for the transport of  $\text{CO}_2$  as bicarbonate in blood is [MP PMT 2012; Kerala PMT 2012]  
 (a) Carboxypeptidase (b) Succinic dehydrogenase  
 (c) Carbonic anhydrase (d) Thrombokinas  
 (e) Lactase
9. The amount of volume of air that can be inspired/expired normally is called [DPMT 2007; AFMC 2009, 10; J & K CET 2010; GUJCET 2014]  
 (a) Tidal volume (b) Vital capacity  
 (c) Residual volume (d) Normal volume
10. The area of inner surface of bronchiole is [KCET 2001; MH CET 2003]  
 (a)  $1 \text{ m}^2$  (b)  $10 \text{ m}^2$   
 (c)  $100 \text{ m}^2$  (d)  $1000 \text{ m}^2$
11. Capacity of human lung for air [Odisha JEE 2005]  
 (a) 3000 ml (b) 1500 ml  
 (c) 1000 ml (d) 500 ml
12. Residual volume is [KCET 2007]  
 (a) Lesser than tidal volume  
 (b) Greater than inspiratory volume  
 (c) Greater than vital capacity  
 (d) Greater than tidal volume
13. Vital capacity of the lung includes [Kerala PMT 2007; DPMT 2007; BHU 2012]  
 Or  
 After forceful inspiration, the amount of air that can be breathed out by maximum forced expiration is equal to [WB JEE 2012]  
 (a)  $\text{IRV} + \text{TV} + \text{ERV}$  (b)  $\text{ERV} + \text{RV}$   
 (c)  $\text{ERV} + \text{TV}$  (d)  $\text{IRV} + \text{TV}$   
 (e)  $\text{RV} + \text{ERV} + \text{TV} + \text{IRV}$
14. Match the items in Column - I with Column - II and choose the correct option
- | Column - I |                            | Column - II |                        |
|------------|----------------------------|-------------|------------------------|
| A.         | Tidal volume               | 1.          | 2500 to 3000 ml of air |
| B.         | Inspiratory reserve volume | 2.          | 1000 ml of air         |
| C.         | Expiratory reserve volume  | 3.          | 500 ml of air          |
| D.         | Residual volume            | 4.          | 3400 to 4800 ml of air |
| E.         | Vital capacity             | 5.          | 1200 ml of air         |
- [NCERT; CBSE PMT 1996; Pb PMT 2004; Kerala PMT 2007; AFMC 2012]
- (a) A-3, B-4, C-2, D-1, E-5  
 (b) A-3, B-1, C-2, D-5, E-4  
 (c) A-3, B-1, C-4, D-5, E-4  
 (d) A-5, B-4, C-2, D-1, E-2  
 (e) A-4, B-3, C-2, D-1, E-5
15. The partial pressure of oxygen in the alveolar air is [Kerala PMT 2010]  
 (a) 45 mm Hg (b) 95 mm Hg  
 (c) 104 mm Hg (d) 110 mm Hg  
 (e) 125 mm Hg
16. The volume of 'anatomical dead space' air is normally [WB JEE 2012]  
 (a) 230 ml (b) 210 ml  
 (c) 190 ml (d) 150 ml
17. The volume and surface area of a deer is  $1,50,000 \text{ cm}^3$  and  $19,000 \text{ cm}^2$  and of a squirrel is  $625 \text{ cm}^3$  and  $530 \text{ cm}^2$ . The area available for heat loss per  $\text{cm}^3$  volume of the squirrel will be approximately [AMU (Med.) 2010]  
 (a) Seven times more than the deer  
 (b) Five times less than the deer  
 (c) Three times more than the deer  
 (d) Eleven times more than the deer
18. The urge to inhale in humans results from [DUMET 2010]  
 (a) Rising  $\text{PCO}_2$  (b) Rising  $\text{PO}_2$   
 (c) Falling  $\text{PCO}_2$  (d) Falling  $\text{PO}_2$
19. Listed below are four respiratory capacities (A-D) and four jumbled respiratory volumes of a normal human adult
- |                                |   |                     |
|--------------------------------|---|---------------------|
| Respiratory capacities         | - | Respiratory volumes |
| (A) Residual volume            | - | 2500 mL             |
| (B) Vital capacity             | - | 3500 mL             |
| (C) Inspiratory reserve volume | - | 1200 mL             |
| (D) Inspiratory capacity       | - | 4500 mL             |
- Which one of the following is the correct matching of two capacities and volumes [CBSE PMT (Pre.) 2010]  
 (a) (A) 4500 mL, (B) 3500 mL  
 (b) (B) 2500 mL, (C) 4500 mL  
 (c) (C) 1200 mL, (D) 2500 mL  
 (d) (D) 3500 mL, (A) 1200 mL

20. Complete and balanced the following reaction  
 $\text{Na}_2\text{HPO}_4 + \text{X} \rightarrow \text{Y} + \text{NaH}_2\text{PO}_4$  [GUJCET 2015]  
 (a)  $\text{X} = \text{NaHCO}_3$ ,  $\text{Y} = \text{NaCl}$   
 (b)  $\text{X} = \text{H}_2\text{CO}_3$ ,  $\text{Y} = \text{NaH}_2\text{CO}_3$   
 (c)  $\text{X} = \text{NaHCO}_3$ ,  $\text{Y} = \text{H}_2\text{CO}_3$   
 (d)  $\text{X} = \text{H}_2\text{CO}_3$ ,  $\text{Y} = \text{NaHCO}_3$
21. Lungs are made up of air-filled sacs, the alveoli. They do not collapse even after forceful expiration because of [NEET 2017]  
 (a) Residual Volume (b) Inspiratory Reserve Volume  
 (c) Tidal Volume (d) Expiratory Reserve Volume

### Process of respiration

1. Oxy-haemoglobin dissociates into oxygen and deoxy-haemoglobin at [DPMT 1992; MP PMT 1995; JIPMER 2002]  
 (a) Low  $\text{O}_2$  pressure in tissue  
 (b) High  $\text{O}_2$  pressure in tissue  
 (c) Equal  $\text{O}_2$  pressure inside and outside tissue  
 (d) All times irrespective of  $\text{O}_2$  pressure
2. In lungs, the air is separated from the venous blood through [CBSE PMT 1997]  
 (a) Squamous epithelium + endothelium of blood vessel  
 (b) Squamous epithelium + tunica media blood vessel  
 (c) Transitional epithelium + tunica external blood vessel  
 (d) None of these
3. The exchange of gases in the alveoli of the lungs takes place by [CBSE PMT 1998; AFMC 2002; Bihar BCECE 2005; Odisha JEE 2010]  
 (a) Osmosis (b) Simple diffusion  
 (c) Passive transport (d) Active transport
4. Which of the following enzymes is absent in mitochondria [CPMT 1998]  
 (a) Aconitase (b) Maleic dehydrogenase  
 (c) Hexokinase (d) None of these
5. If concentration of  $\text{CO}_2$  is more the curve of oxygen will shift towards [MP PMT 2002]  
 Or  
 Increase in body temperature makes oxygen haemoglobin dissociation curve shift to [BHU 2012]  
 (a) Right (b) Left  
 (c) Central (d) None of these
6. The respiratory substrate yielding maximum number of ATP molecules among the following is [CBSE PMT 1994]  
 (a) Glycogen (b) Amylase  
 (c) Ketogenic amino acid (d) Glucose
7. Division of mammalian lungs into a very large number of tiny alveoli around alveolar ducts opening into bronchioles, is [CBSE PMT 1995]  
 (a) An inefficient system of ventilation of alveoli though with very little residual air  
 (b) An inefficient system of ventilating the alveoli resulting in very high percentage of residual air in the lungs  
 (c) A very efficient system of ventilating the alveoli with no residual air  
 (d) An efficient system of ventilation of alveoli with little or no residual air
8. Choose the right sequential phenomena among the following during the delivery of  $\text{O}_2$  from blood to tissue  
 P. Absorption of  $\text{CO}_2$  by the blood  
 Q. Reaction of absorbed  $\text{CO}_2$  with  $\text{H}_2\text{O}$  to form  $\text{H}_2\text{CO}_3$  within RBC and its conversion into  $\text{H}^+$  and  $\text{HCO}_3^-$  ions  
 R. Reaction of absorbed  $\text{CO}_2$  with  $\text{H}_2\text{O}$  in plasma to form  $\text{H}_2\text{CO}_3$  and its conversion into  $\text{H}^+$  and  $\text{HCO}_3^-$  ions  
 S. Combination of  $\text{H}^+$  with haem portion of  $\text{HbO}_2$  to release  $\text{O}_2$   
 T. Combination of  $\text{HCO}_3^-$  with haem portion  $\text{HbO}_2$  to form reduced haemoglobin and release of  $\text{O}_2$  [WB JEE 2012]  
 (a) P, Q, T (b) P, R, S  
 (c) P, Q, S (d) P, R, T
9. The alveoli of lungs are lined by [Kerala PMT 2008]  
 (a) Simple epithelium (b) Squamous epithelium  
 (c) Cuboidal epithelium (d) Columnar epithelium  
 (e) Ciliated epithelium
10. Which of the following is used for long term energy storage by animals [Odisha JEE 2009]  
 (a) Amino acids (b) Glucose  
 (c) Fat (d) Glycogen
11. Intra aortic balloon pump is inflated by [JIPMER 2002]  
 (a) Hydrogen (b) Oxygen  
 (c) Helium (d) Chlorine
12. Energy is stored in the liver and muscles in the form of [CPMT 1998; MP PMT 1999; AFMC 2003; Odisha JEE 2009]  
 Or  
 In the muscles carbohydrates are stored in the form of [WB JEE 2016]  
 (a) Carbohydrates (b) Glycogen  
 (c) Fat (d) Protein
13. The major fraction of  $\text{CO}_2$  released during cellular respiration is transported by the blood to the lung capillaries [NCERT; CPMT 1998; MP PMT 1998, 2002; AIEEE Pharmacy 2003; Odisha JEE 2010]  
 Or  
 Approximately seventy percent of carbon-dioxide absorbed by the blood will be transported to the lungs [CBSE PMT 2014]  
 (a) In combination with haemoglobin  
 (b) As free  $\text{CO}_2$   
 (c) As carbonic acid or  $\text{H}_2\text{CO}_3$   
 (d) In the form of bicarbonate ions
14. The amount of  $\text{O}_2$  transported in a dissolved state through plasma is approximately [NCERT; Kerala PMT 2012]  
 (a) 97% (b) 20–25%  
 (c) 7% (d) 49%  
 (e) 3%
15. During inspiration the diaphragm [BHU 2004; CPMT 2010]  
 (a) Relaxes to become dome-shaped  
 (b) Contracts and flattens  
 (c) Expands  
 (d) Shows no change

16. In hurdle race, which of the following is accumulated in the leg muscle [DUMET 2009]  
 (a) Performed ATP (b) Glycolysis  
 (c) Lactate (d) Oxidative metabolism
17. Which of the following sets is most correct for the catabolism of an 18 carbon fatty acid [AMU (Med.) 2009]  
 (a) Mitochondria, beta-oxidation, 140 ATP molecules  
 (b) Cytosol, beta oxidation, 146 ATP molecules  
 (c) Mitochondria, beta oxidation, 146 ATP molecules  
 (d) Cytosol, beta oxidation, 140 ATP molecules
18. In humans, which among these is not a step in respiration [NCERT; Kerala PMT 2012]  
 (a) Pulmonary ventilation  
 (b) Alveolar diffusion of  $O_2$  and  $CO_2$   
 (c) Transport of gases by blood  
 (d) Diffusion of  $O_2$  and  $CO_2$  between blood and tissues  
 (e) Utilization of  $CO_2$  by cells for catabolic reactions
19. Hb is a [MP PMT 2007]  
 (a) Reproductive pigment (b) Respiratory pigment  
 (c) Carbohydrate (d) Fat
20. According to Boyle's law, the product of pressure and volume is a constant. Hence, [KCET 2010]  
 (a) If volume of lungs is increased, the pressure decreases, proportionately  
 (b) If volume of lungs is increased, the pressure also increases proportionately  
 (c) If volume of lungs is increased, the pressure decreases disproportionately  
 (d) If volume of lungs is increased, the pressure remains the same
21. Chloride shift occurs in respond to [DPMT 2007]  
 (a)  $H^+$  (b)  $K^+$   
 (c)  $HCO_3^-$  (d)  $Na^+$
22. Which one of the following is a possibility for most of us in regards to breathing, by making a conscious effort [NCERT; CBSE PMT (Mains) 2011]  
 (a) One can consciously breathe in and breathe out by moving the diaphragm alone, without moving the ribs at all  
 (b) The lungs can be made fully empty by forcefully breathing out all air from them  
 (c) One can breathe out air totally without oxygen  
 (d) One can breathe out air through eustachian tubes by closing both the nose and the mouth
23. Identify the correct statement with reference to transport of respiratory gases by blood [KCET 2006]  
 (a) Haemoglobin is necessary for transport of carbon dioxide and carbonic anhydrase for transport of oxygen  
 (b) Haemoglobin is necessary for transport of oxygen and carbonic anhydrase for transport of carbon dioxide  
 (c) Only oxygen is transported by blood  
 (d) Only carbon dioxide is transported by blood
24. Which of the following statement correctly defines "Bohr effects"  
 (a) Rise in  $PCO_2$  with a decrease in  $CO_2$  concentration  
 (b) Rise in  $PCO_2$  with an increase in  $CO_2$  concentration  
 (c) Rise in  $PCO_2$  with an increase in  $CO_2$  and decrease in  $PO_2$   
 (d) Rise in  $PCO_2$  with a decrease in pH (concentration at which 50% haemoglobin of blood is saturated with oxygen)
25. Under a given concentration in blood, dissociation of oxyhaemoglobin will increase if  
 (a) pH of blood falls  
 (b) pH of blood rises  
 (c)  $CO_2$  concentration in blood falls  
 (d) Free fatty acid concentration in blood falls
26. Oxygen binding to haemoglobin in blood is [AIIMS 2012]  
 (a) Directly proportional to the concentration of  $CO_2$  in the medium  
 (b) Inversely proportional to the concentration of  $CO_2$  in the medium  
 (c) Directly proportional to the concentration of CO in the medium  
 (d) Independent of the concentration of CO in the medium
27. Bulk of carbon dioxide ( $CO_2$ ) released from body tissues into the blood is present as [NCERT; CBSE PMT (Mains) 2011]  
 (a) 70% carbamino-haemoglobin and 30% as bicarbonate  
 (b) Carbamino-haemoglobin in RBCs  
 (c) Bicarbonate in blood plasma and RBCs  
 (d) Free  $CO_2$  in blood plasma
28.  $O_2$  dissociation curve is [NCERT; BHU 1995, 2000; CPMT 2000; DPMT 2007]  
 (a) Sigmoid (b) Slope  
 (c) Straight line (d) Parabola
29. In expiration condition, diaphragm becomes [CPMT 1993]  
 (a) Circular (b) Relaxed  
 (c) Fully contracted (d) Expanded
30. Maximum amount of oxygen is lost from the blood in the [KCET 2006]  
 (a) Capillaries surrounding the tissue cells  
 (b) Arteries of the body  
 (c) Capillaries surrounding the alveoli  
 (d) Left auricle of the heart
31. Which of the following activity does not take place during pulmonary respiration [Bihar MDAT 1995]  
 (a) Movement of buccal cavity  
 (b) Contraction and relaxation of sternohyal and pterohyal muscles  
 (c) Successive opening and closing of mouth and external nostrils  
 (d) All the above  
 (e) No activity takes place
32. In anaerobic respiration the pyruvic acid in muscle will form [CPMT 1995, 99; AFMC 2002, 08; DPMT 2003]  
 (a) Lactic acid ( $C_3H_6O_3$ ) and  $H_2O$   
 (b) Alcohol ( $C_2H_5OH$ ) and  $H_2O$   
 (c) Acetaldehyde and  $H_2O$   
 (d) Acetyl CoA and  $H_2O$
33. Blood contains  $CO_2$  in which of the following forms  
 (a)  $NaHCO_3$  (b) Carbonic acid  
 (c)  $Hb-CO_2$  (d)  $Hb-CO_2$  and CO

34. Oxygen is transported to every cell of the body through (MP PMT 1994)  
 (a) RBC (b) WBC  
 (c) RBC and WBC (d) RBC and hormones
35. Acquiring an oxygen debt is evidence that (CPMT 2005)  
 (a)  $O_2$  cannot be stored in tissue  
 (b) Aerobic respiration is more complex than glycolysis  
 (c) Lactic acid can be converted into glycogen  
 (d) Anaerobic process are slower than aerobic processes
36. The dissociation curve is associated with (NCERT)  
 (a) Oxygen (b) Oxyhaemoglobin  
 (c) Carbon dioxide (d) Carbonic anhydrase
37. Respiratory system is derived from (CPMT 1993)  
 (a) Ectoderm (b) Mesoderm  
 (c) Endoderm (d) None of these
38. The breakdown product of haemoglobin is called as (CBSE PMT 1993)  
 (a) Iron (b) Bilirubin  
 (c) Haemocyanin (d) Skatol
39. During respiration  $CO_2$  is transported in the form of (NCERT; CBSE PMT 1995, 2006; AFMC 2006, 10; BHU 2006)  
 (a) Dissolved plasma  
 (b) Sodium carbonate  
 (c)  $KHCO_3$   
 (d) Partly dissolved in plasma and partly in the form of sodium and potassium bicarbonate
40.  $CO_2$  is dissolved in haemoglobin or blood plasma as (CBSE PMT 1993; WB JEE 2016)  
 (a) Carbonates (b) Bicarbonates  
 (c) Oxyhaemoglobin (d) Carboxyhaemoglobin
41. The factor which does not affect the rate of alveolar diffusion is (NCERT; Kerala PMT 2011)  
 (a) Solubility of gases (b) Thickness of the membranes  
 (c) Pressure gradient (d) Concentration gradient  
 (e) Reactivity of the gases
42. In Bhor's effect curve shift to right (Bihar CECE 2006)  
 (a)  $P_{50}$   $CO_2$  decreases and  $P_{50}$   $O_2$  increases  
 (b)  $P_{50}$   $CO_2$  increases and  $P_{50}$   $O_2$  decreases  
 (c)  $P_{50}$   $CO_2$  increases and  $P_{50}$   $O_2$  increases  
 (d)  $P_{50}$   $CO_2$  increases and  $P_{50}$   $O_2$  decreases and pH increases
43. The figure given below shows a small part of human lung where exchange of gases takes place. In which one of the option given below, the one part A, B, C or D is correctly identified along with its functions
- 
- Options (CBSE PMT (Pre.) 2011)  
 (a) B : Red blood cell – transport of  $CO_2$  mainly  
 (b) C : Arterial capillary – passes oxygen to tissues  
 (c) A : alveolar cavity – main site of exchange of respiratory gases  
 (d) D : Capillary wall – exchange of  $O_2$  and  $CO_2$  takes place here
44. Reduction in pH of blood will (NEET (Phase-I) 2016)  
 (a) Reduce the rate of heart beat  
 (b) Reduce the blood supply to the brain  
 (c) Decrease the affinity of hemoglobin with oxygen  
 (d) Release bicarbonate ions by the liver
45. When you hold your breath, which of the following gas changes in blood would first lead to the urge to breathe (AIPMT (Cancelled) 2015)  
 (a) Rising  $CO_2$  concentration  
 (b) Falling  $CO_2$  concentration  
 (c) Rising  $CO_2$  and falling  $O_2$  concentration  
 (d) Falling  $O_2$  concentration
46. In lungs there is definite exchange of ions between RBC and plasma. Removal of  $CO_2$  from blood involves (CPMT 2005)  
 (a) Influx of  $Cl^-$  ions into RBC  
 (b) Influx of  $HCO_3^-$  ions into RBC  
 (c) Efflux of  $Cl^-$  ions into RBC  
 (d) Efflux of  $HCO_3^-$  ions into RBC
47. In a minute normal man respires (NCERT; MP PMT 1993)  
 (a) 10 times (b) 16 times  
 (c) 30 times (d) 4 times
48. The process by which chloride ions pass into R.B.C. and bicarbonate ions pass out is called (DPMT 1992; RPMT 1999; Kerala CET 2003)  
 (a) Bicarbonate shift (b) Chloride shift  
 (c) Buffer system (d) Enzyme shift
49. Following diagram indicates the mechanism of breathing. Identify all the parts A, B, C and D correctly (NCERT)
- 
- (a) A – Air expelled from lungs; B – Ribs and sternum raised; C – Diaphragm contracted; D – Volume of thorax decreased  
 (b) A – Air expelled from lungs; B – Ribs and sternum raised; C – Diaphragm relaxed; D – Volume of thorax decreased  
 (c) A – Air expelled from lungs; B – Ribs and sternum return to original position; C – Diaphragm relaxed; D – Volume of thorax decreased  
 (d) A – Air entering into lungs; B – Ribs and sternum raised; C – Diaphragm contracted; D – Volume of thorax raised
50. Muscles which help in respiration are  
 (a) Sternum and petrohyal (b) Sternohyal and petrohyal  
 (c) Jugal and tendons (d) None of these



51. Of the following, the one which is an example of buffer system in blood is [Kerala PMT 2004]  
 (a) Haemoglobin and oxyhaemoglobin  
 (b) Oxygen and carbon dioxide  
 (c) Albumin and globulin  
 (d) Sodium bicarbonate and carbonic acid
52. In a normal man to help the transport of  $O_2$  and  $CO_2$  properly, the blood is  
 (a) Slightly alkaline (b) Slightly acidic  
 (c) Strongly alkaline (d) Strongly acidic
53. In mammals how much  $CO_2$  is transported as bicarbonates of sodium and potassium in the blood [AIIMS 1993]  
 (a) 5–10 % (b) 10–90 %  
 (c) 70–72 % (d) 90–95 %
54. A large proportion of oxygen is left unused the human blood even after its uptake by the body tissue. This  $O_2$  [NCERT; CBSE PMT (Pre.) 2011]  
 (a) Helps in releasing more  $O_2$  to the epithelium tissues  
 (b) Acts as a reserve during muscular exercise  
 (c) Raises the  $pCO_2$  of blood to 75 mm of Hg  
 (d) Is enough to keep oxyhaemoglobin saturation at 96%
55. Chloride shift is essential for the transport of [CBSE PMT 1990]  
 (a)  $CO_2$  and  $O_2$  (b)  $N_2$   
 (c)  $CO_2$  (d)  $O_2$
56. Which is true for  $CO_2$  concentration [Odisha JEE 2004]  
 (a) More in alveolar air than in expired air  
 (b) More in expired air than in alveolar air  
 (c) More in inspired air than in expired air  
 (d) More in inspired air than in alveolar air
57. The two waste products of oxidation in cells are  
 (a)  $CO_2$  and  $N_2$  (b) C and O  
 (c)  $CO_2$  and water (d) Water and  $N_2$
58. The function of tracheal hair is to [BVP 2003]  
 (a) Pass mucus out (b) Pass mucus in  
 (c) Pass air out (d) Pass air in
59. The function of surfactant is/are [J & K CET 2012]  
 (a) Facilitating lung expansion  
 (b) Maintaining the stable size of the alveoli  
 (c) To reduce the surface tension on the alveoli  
 (d) All the above
60. During cellular respiration the energy produced is stored in  
 Or  
 The common immediate source of energy in cellular activity  
 (a) Protoplasm (b) Cytoplasm  
 (c) ATP (d) Nucleus
61. Exhalation is the process of expulsion of air through the respiratory tract. Which figure correctly shows the process of exhalation [NCERT]
- 
62. Respiration is the physiological process in which  
 (a) Breathing occurs  
 (b) Breathing and external respiration occur  
 (c) Breathing, external respiration and cellular respiration occur  
 (d) Only inspiration occurs
63. In rabbit the inspiration occurs by contraction of  
 (a) External intercostal muscles and muscles of the diaphragm  
 (b) Internal intercostal muscles and muscles of the diaphragm  
 (c) External intercostal muscles only  
 (d) Muscles of the diaphragm only
64. Left shift of oxyhaemoglobin curve is noticed under [EAMCET 2009]  
 (a) Normal temperature and pH  
 (b) Low temperature and high pH  
 (c) Low pH and high temperature  
 (d) Low pH and low temperature
65. Lungs do not collapse between breaths and some air always remains in the lungs which can never be expelled because [NEET (Phase-II) 2016]  
 (a) Pressure in the lungs is higher than the atmospheric pressure  
 (b) There is a negative pressure in the lungs  
 (c) There is a negative intrapleural pressure pulling at the lung walls  
 (d) There is a positive intrapleural pressure
66. The partial pressure of oxygen in the alveoli of the lungs is [NEET (Phase-II) 2016]  
 (a) Less than that of carbon dioxide  
 (b) Equal to that in the blood  
 (c) More than that in the blood  
 (d) Less than that in the blood

### Control of breathing

1. How much amount of air can be inspired or expired during normal breathing [DPMT 2003; BVP 2004]  
 (a) 0.5 l (b) 2.5 l  
 (c) 1.5 l (d) 5.5 l

2. Breathing differs from respiration by [AFMC 1993]
  - (a) Both are same and there is no difference
  - (b) Breathing refers to respiration in human beings whereas respiration occurs in rest of the animals and plants
  - (c) Breathing refers to chest movements due to inhalation of  $O_2$  and exhalation of carbon dioxide whereas respiration refers to gaseous exchange
  - (d) None of these
3. The air which is taken in or given out during a single breath is known as [Kerala CET 2002; BHU 2008]
  - (a) Residual air
  - (b) Vital air
  - (c) Tidal air
  - (d) All of these
4. Combination of haemoglobin with  $O_2$  in lungs can be promoted by [MP PMT 2006]
  - (a) Increasing  $CO_2$  concentration in blood
  - (b) Increasing  $O_2$  concentration in blood
  - (c) Decreasing  $O_2$  concentration in blood
  - (d) Introducing CO in blood
5. Step of respiration are controlled by [RPMT 2005]
  - (a) Substrates
  - (b) Enzymes
  - (c) Hormone
  - (d) Bile juice
6. Respiration mechanism is controlled by
  - a) Central nervous system
  - b) Autonomic nervous system
  - c) Sympathetic nervous system
  - d) Parasympathetic nervous system
7. Which of the following conditions is responsible for increase in ventilation rate of lungs [CPMT 2005]
  - (a) Increase of  $CO_2$  content in inhaled air
  - (b) Increase of  $CO_2$  content in exhaled air
  - (c) Decrease of  $O_2$  content in inhaled air
  - (d) Decrease of  $O_2$  content in exhaled air
8. The respiratory centre in brain which controls inspiration and expiration is situated in [CPMT 1993, 99; CBSE PMT 1994, 99; BHU 1995; AFMC 1995; RPMT 1995, 99, 2005, 06; MP PMT 1996; Pb. PMT 1999; AIIMS 2001; Kerala PMT 2010]
 

Or

Respiratory and vomiting centres are located in [NCERT; MH CET 2002; DUMET 2009]

  - (a) Medulla oblongata
  - (b) Cerebellum
  - (c) Hypothalamus
  - (d) Pericardium
9. When  $CO_2$  concentration in blood increases, breathing becomes [CPMT 2004]
  - (a) Slow and deep
  - (b) Faster and deeper
  - (c) Shallower and slow
  - (d) There is no effect on breathing
10. Respiratory centre of brain is sensitive to [NCERT; Odisha JEE 2004]
  - (a) More  $O_2$  conc. in blood
  - (b) More  $CO_2$  conc. in blood
  - (c) Accumulation of blood in brain
  - (d) All of these
11. A substance that prevents or delays oxidation is [J & K CET 2005]
  - (a) Bactericidal
  - (b) Hormone
  - (c) Antioxidant
  - (d) Enzyme

12. Rate of breathing is controlled by [Kerala CET 2005]
  - (a) The amount of freely available oxygen
  - (b) Carbon dioxide
  - (c) Muscular function of the body
  - (d) Stress

### Important concepts of respiration

1. What is R.Q. for human fat [DPMT 1992]
  - (a) 0.673
  - (b) 0.655
  - (c) 0.703
  - (d) 0.825
2. The form of energy used in respiration is [CPMT 1993]
  - (a) Chemical energy
  - (b) Electrical energy
  - (c) Mechanical energy
  - (d) Radiant energy
3. In human blood, the oxygen carrier is [CPMT 1994]
  - (a) Iron
  - (b) Meth-haemoglobin
  - (c) Haemocyanin
  - (d) Haemoglobin
4. The toxic effect of carbon monoxide is due to its greater affinity for haemoglobin as compared to oxygen, approximately by [BHU 2002]
  - (a) 2 times
  - (b) 20 times
  - (c) 200 times
  - (d) 1000 times
5. During strenuous exercise, which of the following change occurs [CPMT 2000]
  - (a) Glucose is converted into glycogen
  - (b) Glucose is converted into pyruvic acid
  - (c) Starch is converted into glucose
  - (d) Pyruvic acid is converted into lactic acid
6. Which of the following blood vessels in the circulatory system of frog has more oxygenated blood [AFMC 2006]
  - (a) Pulmocutaneous artery
  - (b) Pulmocutaneous vein
  - (c) Pulmonary artery
  - (d) Precaval veins

### Disorders of respiration system

1. After fast running, man has fast heart beat, slow pulse and shallow breathing, in such conditions he has
  - (a) Oxygen debt
  - (b) Poisoning due to lactic acid
  - (c) No pulmonary pressure
  - (d) Weak heart
2. Increased asthmatic attacks in certain seasons are related to [CBSE PMT 2007; MP PMT 2013]
  - (a) Hot and humid environment
  - (b) Eating fruits preserved in tin containers
  - (c) Inhalation of seasonal pollen
  - (d) Low temperature
3. After taking a long deep breath we do not respire for some seconds due to [BHU 2005]
  - (a) More  $CO_2$  in blood
  - (b) More  $O_2$  in blood
  - (c) Less  $CO_2$  in blood
  - (d) Less  $O_2$  in blood
4. Ascent of high mountains may cause altitude sickness in men. Prime cause of this is [NCERT; CPMT 2005]
  - (a) Excess of  $CO_2$  in blood
  - (b) Decreased efficiency of haemoglobin
  - (c) Decreased partial pressure of oxygen
  - (d) Decreased proportion of oxygen in air



5. The state during which the respiratory centre is inhibited is termed as [DPMT 1993]  
 (a) Asphyxia (b) Suffocation  
 (c) Anoxia (d) Chocking
6. Ravi, who lived at sea level, had around 5 million RBC per cubic millimeter of his blood. Later when he lived at an altitude of 18,000 ft, showed around 8 million RBC per cubic millimeter of blood. This is an adaptation because [AIEEE Pharmacy 2004; RPMT 2005]  
 (a) At high altitude he ate more nutritive food  
 (b) He had pollution free air to balance breathe  
 (c) At high altitude  $O_2$  level is less hence more RBCs were required to absorb enough oxygen  
 (d) At high altitude there is more UV radiation which enhances RBCs production
7. During rest, the metabolic needs of the body are at their minimum. Which of the following is indicative of this situation [AFMC 1994]  
 (a) Rate of breathing (b) Pulse rate  
 (c)  $O_2$  intake and  $CO_2$  output (d) All of these
8. Cyanosis is  
 (a) Lack of oxygen in body fluids  
 (b) Difficult or heavy breathing  
 (c) Excess of carbon dioxide in the body fluids  
 (d) 'Skin turning blue' due to excessive amount of deoxygenated haemoglobin in the skin blood vessels
9. Pneumotaxis centre is associated with  
 (a) Breathing (b) Respiration  
 (c) Movement (d) Closure of glottis
10. Congestion of the lungs is one of the main symptoms in [Kerala PMT 2011]  
 (a) Hypotension (b) Coronary artery disease  
 (c) Angina (d) Heart failure  
 (e) Atherosclerosis
11. When  $O_2$  is inadequate during respiration, the condition is called [BVP 2000; WB JEE 2011; Odisha JEE 2012]  
 (a) Anoxia (b) Pleurisy  
 (c) Asphyxia (d) Hypoxia
12. The oxygen toxicity is related with [BHU 2004]  
 (a) Blood poisoning  
 (b) Collapse of alveolar walls  
 (c) Failure of ventilation of lungs  
 (d) Both (a) and (b)
13. The diabetic patient shows  
 (a) High respiratory quotient (b) Low respiratory quotient  
 (c) Zero respiratory quotient (d) None of these
14. The 'blue baby' syndrome results from [CBSE PMT 2006]  
 (a) Excess of dissolved oxygen  
 (b) Excess of TDS (total dissolved solids)  
 (c) Excess of chloride  
 (d) Methaemoglobin
15. Asthma is characterised by [NCERT; Odisha JEE 2011]  
 (a) Spasm in bronchial muscle  
 (b) Alveolar wall degradation  
 (c) Pain in lungs  
 (d) Damage in diaphragm
16. In which disease, due to flattening of tracheal vessels, alveoli are deprived of oxygen [NCERT; GUJCET 2007]  
 Or  
 Name the pulmonary disease in which alveolar surface area involved in gas exchange is drastically reduced due to damage in the alveolar walls [AIPMT 2015]  
 (a) Bronchitis (b) Asthma  
 (c) Pneumonia (d) Emphysema
17. Blood analysis of a patient reveals an unusually high quantity of carboxyhaemoglobin content. Which of the following conclusions is most likely to be correct [CPMT 2004]  
 (a) Carbon dioxide (b) Carbon monoxide  
 (c) Carbon disulphide (d) Chloroform

## Q NCERT Exemplar Questions

1. Respiration in insects is called direct because [NCERT]  
 (a) The tissues exchange  $O_2/CO_2$  directly with the air in the tubes  
 (b) The tissues exchange  $O_2/CO_2$  directly with coelomic fluid  
 (c) The tissues exchange  $O_2/CO_2$  directly with the air outside through body surface  
 (d) Tracheal tubes exchange  $O_2/CO_2$  directly with the haemocoel which then exchange with tissues
2. Regarding the functions of our respiratory system, mark the wrong entry [NCERT]  
 (a) Humidifies the air (b) Warms up the air  
 (c) Diffusion of gases (d) Cleans up the air
3. A person suffers punctures in his chest cavity in an accident, without any damage to the lungs its effect could be [NCERT]  
 (a) Reduced breathing rate  
 (b) Rapid increase in breathing rate  
 (c) No change in respiration  
 (d) Cessation of breathing
4. Mark the true statement among the following with reference to normal breathing [NCERT]  
 (a) Inspiration is a passive process where as expiration is active  
 (b) Inspiration is a active process where as expiration is passive  
 (c) Inspiration and expiration are active processes  
 (d) Inspiration and expiration are passive processes
5. A person breathes in some volume of air by forced inspiration after having a forced expiration. This quantity of air taken in is [NCERT]  
 (a) Total lung capacity (b) Tidal volume  
 (c) Vital capacity (d) Inspiratory capacity
6. Mark the incorrect statement in context to  $O_2$  binding to Hb [NCERT]  
 (a) Higher pH (b) Lower temperature  
 (c) Lower  $pCO_2$  (d) Higher  $PO_2$

7. Mark the correct pair of muscles involved in the normal breathing in humans [NCERT]  
 (a) External and internal intercostals muscles  
 (b) Diaphragm and abdominal muscles  
 (c) Diaphragm and external intercostals muscles  
 (d) Diaphragm and internal intercostals muscles
8. Incidence of Emphysema – a respiratory disorder is high in cigarette smokers. In such cases [NCERT]  
 (a) The bronchioles are found damaged  
 (b) The alveolar walls are found damaged  
 (c) The plasma membrane is found damaged  
 (d) The respiratory muscles are found damaged
9. Respiratory process is regulated by certain specialized centres in the brain. One of the following listed centres can reduce the inspiratory duration upon stimulation [NCERT]  
 (a) Medullary inspiratory centre (b) Pneumotaxic centre  
 (c) Apneustic centre (d) Chemosensitive centre
10.  $\text{CO}_2$  dissociates from carbamino haemoglobin when [NCERT]  
 (a)  $p\text{CO}_2$  is high and  $p\text{O}_2$  is low  
 (b)  $p\text{O}_2$  is high and  $p\text{CO}_2$  is low  
 (c)  $p\text{CO}_2$  and  $p\text{O}_2$  are equal  
 (d) None of the above
11. Identify the correct and incorrect match about respiratory volume and capacities and mark the correct answer  
 (i) Inspiratory capacity (IC) = Tidal Volume + Residual volume  
 (ii) Vital Capacity (VC) = Tidal Volume (TV) + Inspiratory Reserve Volume (IRV) + Expiratory Reserve Volume (ERV)  
 (iii) Residual Volume (RV) = Vital Capacity (VC) – Inspiratory Reserve Volume (IRV)  
 (iv) Tidal Volume (TV) = Inspiratory Capacity (IC) – Inspiratory Reserve Volume (IRV)  
 Options. [NCERT]  
 (a) (i) Incorrect, (ii) Incorrect, (iii) Incorrect, (iv) Correct  
 (b) (i) Incorrect, (ii) Correct, (iii) Incorrect, (iv) Correct  
 (c) (i) Correct, (ii) Correct, (iii) Incorrect, (iv) Correct  
 (d) (i) Correct, (ii) Incorrect, (iii) Correct, (iv) Incorrect
12. The oxygen – haemoglobin dissociation curve will show a right shift in case of [NCERT]  
 (a) High  $p\text{CO}_2$  (b) High  $p\text{O}_2$   
 (c) Low  $p\text{CO}_2$  (d) Less  $\text{H}^+$  concentration
13. Match the following and mark the correct options
- | Animal                | Respiratory organ |
|-----------------------|-------------------|
| A. Earthworm          | i. Moist cuticle  |
| B. Aquatic Arthropods | ii. Gills         |
| C. Fishes             | iii. Lungs        |
| D. Birds/Reptiles     | iv. Trachea       |
- Options [NCERT]  
 (a) A-ii, B-i, C-iv, D-iii (b) A-i, B-iv, C-ii, D-iii  
 (c) A-i, B-iii, C-ii, D-iv (d) A-i, B-ii, C-iv, D-iii

## Critical Thinking

### Objective Questions

- Which animal has unpaired lungs  
 (a) Monkey (b) Whale  
 (c) Some frogs (d) Some snakes
- Mammalian lungs have enormous number of minute alveoli (air sacs). It is to allow [AFMC 1994; MP PMT 1995]  
 (a) More space for increasing the volume of inspired air  
 (b) More surface area for diffusion of gases  
 (c) More spongy texture for keeping lungs in proper shape  
 (d) More nerve supply to keep organs active when working
- True organ of sound production in birds is [Kerala CET 2003]  
 (a) Larynx (b) Sound box  
 (c) Vocal sac (d) Syrinx
- The nerve impulses which stimulate the intercostal muscles and diaphragm and thus permit breathing, originate in the [AIIMS 1992]  
 (a) Cerebellum (b) Pons  
 (c) Hypothalamus (d) Medulla oblongata
- Number of alveoli in human lung is about [Odisha JEE 2012]  
 (a) One million (b) More than two millions  
 (c) More than five millions (d) More than seven millions
- Which of the following statements is not true [Kerala PMT 2007]  
 (a) The partial pressure of oxygen in deoxygenated blood is 40 mm Hg  
 (b) The partial pressure of oxygen in oxygenated blood is 95 mm Hg  
 (c) The partial pressure of oxygen in the alveolar air is 104 mm Hg  
 (d) The partial pressure of carbon dioxide in the alveolar air is 40 mm Hg  
 (e) The partial pressure of carbon dioxide in deoxygenated blood is 95 mm Hg
- Which option is completely correct for the given statements  
 Statement 1 – The nerve impulse ordered by respiratory centre passes through nerve to the diaphragm and the intercostal muscles and regulates respiration  
 Statement 2 – Respiratory centres scatterly located in the brain stem gives of rhythmic stimuli to diaphragm and respiratory muscle and regulate respiration [GUJCET 2014]  
 (a) First statement is correct and second statement is wrong  
 (b) First statement is wrong and second statement is correct  
 (c) Both of the statements are wrong  
 (d) Both of the statements are correct
- The impulse for voluntary muscles for forced breathing starts in  
 (a) Medulla (b) Vagus nerve  
 (c) Cerebrum (d) Cerebellum



9. How much  $\text{CO}_2$  is present per 100 ml of venous blood  
 (a) 52.1 ml (b) 3.7 ml  
 (c) 40 ml (d) 20 ml
10. Which of the following statements are true / false  
 A. The blood transports  $\text{CO}_2$  comparatively easily because of its higher solubility  
 B. Approximately 8.9% of  $\text{CO}_2$  is transported being dissolved in the plasma of blood  
 C. The carbon dioxide produced by the tissues, diffuses passively into the blood stream and passes into red blood corpuscles and react with water to form  $\text{H}_2\text{CO}_3$   
 D. The oxyhaemoglobin ( $\text{HbO}_2$ ) of the erythrocytes is basic  
 E. The chloride ions diffuse from plasma into the erythrocytes to maintain ionic balance  
 [Kerala PMT 2006]  
 (a) A, C and E are true, B and D are false  
 (b) A, C and E are false, B and D are true  
 (c) A, B and D are true, C and E are false  
 (d) A, B and D are false, C and E are true  
 (e) A, B and C are true, D and E are false
11. Which one of the following is the correct statement for respiration in humans [NCERT; CBSE PMT (Pre.) 2012]  
 (a) Cigarette smoking may lead to inflammation of bronchi  
 (b) Neural signals from pneumotoxic centre in pons region of brain can increase the duration of inspiration  
 (c) Workers in grinding and stone-breaking industries may suffer, from lung fibrosis  
 (d) About 90% of carbon dioxide ( $\text{CO}_2$ ) is carried by haemoglobin as carbamino haemoglobin
12. Concentration of carbonic acid does not increase in blood due to the presence of  
 (a)  $\text{Na}^+$  (b)  $\text{K}^+$   
 (c)  $\text{Ca}^{++}$  (d)  $\text{Mg}^{++}$
13. A pyrophosphate cleavage takes place when [CPMT 1998]  
 (a) ATP is converted into AMP  
 (b) ATP is converted into ADP  
 (c) ADP is converted into AMP  
 (d) AMP is converted into ATP
14. Haemoglobin is having maximum affinity with [CPMT 1995; MP PMT 1999; RPMT 1999]  
 (a)  $\text{CO}_2$  (b) CO  
 (c)  $\text{O}_2$  (d)  $\text{NH}_3$
15. When a man inhales air containing normal concentration of  $\text{O}_2$  as well as CO he suffers from suffocation because [AIIMS 1993; BVP 2003]  
 (a) CO reacts with  $\text{O}_2$  reducing its percentage in air  
 (b) Haemoglobin combines with CO instead of  $\text{O}_2$  and the product cannot dissociate  
 (c) CO affects diaphragm and intercostal muscles  
 (d) CO affects the nerve of the lungs
16. Which two of the following changes (A–B) usually tend to occur in the plain dwellers when they move to high altitudes (3500 m or more)  
 (A) Increase in red blood cell size  
 (B) Increase in red blood cell production  
 (C) Increased breathing rate  
 (D) Increase in thrombocyte count  
 Changes occurring are [CBSE PMT (Pre.) 2010]  
 (a) (A) and (B) (b) (B) and (C)  
 (c) (C) and (D) (d) (A) and (D)
17. If a person breathes with maximal effort but with his nose and mouth closed, the alveolar pressure can be decreased to as low as  
 (a)  $-80 \text{ mm Hg}$  (b)  $+10 \text{ mm Hg}$   
 (c)  $-180 \text{ mm Hg}$  (d)  $-250 \text{ mm Hg}$
18. Rate of respiration is directly proportional to [CPMT 1993]  
 (a) Concentration of oxygen in blood  
 (b) Concentration of carbon dioxide in blood  
 (c) Oxygen in trachea  
 (d) Diaphragm expansion
19. If a man from sea coast goes to Everest peak then [CPMT 1996; MP PMT 2002]  
 (a) His breathing and heart beat will increase  
 (b) His breathing and heart beat will decrease  
 (c) His respiratory rate will decrease  
 (d) His heart beat will decrease
20. Exposure to carbon monoxide (from coal gas) is extremely dangerous and can kill a patient because [NCERT; KCET 1996]  
 (a) The compound carboxyhaemoglobin ( $\text{COHb}$ ) it forms with haemoglobin can gradually clot the blood resulting in circulatory failure  
 (b)  $\text{COHb}$  reduces the ability of blood for transport oxygen by rupturing a vast majority of erythrocytes  
 (c)  $\text{COHb}$  greatly modifies the structure of haemoglobin, thus making it lose its affinity for oxygen  
 (d) None of the above
21. Blood does not transport oxygen in [CPMT 1992]  
 (a) Cockroach (b) Earthworm  
 (c) Frog's tadpole (d) Mammalian foetus
22. Forced deep breathing for a few minutes by a person sitting at rest may be followed by a temporary cessation of breathing. This is due to  
 (a) Too much  $\text{O}_2$  in the blood  
 (b) Too much  $\text{CO}_2$  in the blood  
 (c) Very little  $\text{CO}_2$  in the blood  
 (d) Both too much  $\text{O}_2$  and very little  $\text{CO}_2$  in the blood
23. Hamburger phenomenon is also known as [CMC Vellore 1993; AIIMS 1993; BHU 2001, 08; JIPMER 2002; MP PMT 2007, 09, 10]  
 (a) Hydrogen shift mechanism  
 (b) Chloride shift mechanism  
 (c) Carbonic acid shift mechanism  
 (d) Sodium-potassium pump

## 840 Breathing and Exchange of Gases

24. In an accident, a man dies immediately although there was no injury to brain, kidney, stomach and heart. The probable cause of death may be  
 (a) Coagulation of RBC  
 (b) Digestion stopped  
 (c) Diaphragm got punctured  
 (d) Larynx got punctured
25. Buccopharyngeal respiration in frog [MP PMT 2000]  
 (a) Is increased when nostrils are closed  
 (b) Stops when there is pulmonary respiration  
 (c) Is increased when it is catching fly  
 (d) Stops when mouth is opened
26. Name the chronic respiratory disorder caused mainly by cigarette smoking [NEET (Phase-I) 2016]  
 (a) Emphysema (b) Asthma  
 (c) Respiratory acidosis (d) Respiratory alkalosis
27. Asthma may be attributed to [NEET (Phase-I) 2016]  
 (a) Bacterial infection of the lungs  
 (b) Allergic reaction of the mast cells in the lungs  
 (c) Inflammation of the trachea  
 (d) Accumulation of fluid in the lungs
28. Which of the following statement(s) is/are correct [WB JEE 2016]  
 (a) Silicosis is the result of exposure to silica that causes permanent lung damage and death  
 (b) Transportation of gases and digested food materials in the body of higher animals causes muscle weakness and fatigue  
 (c) ADH is a neurohypophysial hormone that regulates body water  
 (d) Myasthenia gravis is a neuromuscular disease that is mediated by circulatory system

## R Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

- (a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion  
 (b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion  
 (c) If the assertion is true but the reason is false  
 (d) If both the assertion and reason are false  
 (e) If the assertion is false but reason is true

1. Assertion : Aerobic animals are not truly aerobic.  
 Reason : They produce lactic acid anaerobically.
2. Assertion : Coughing and sneezing are necessary.  
 Reason : Coughing and sneezing are reflex actions.
3. Assertion : Most fish when out of water, die of suffocation.  
 Reason : Atmospheric air contains far less oxygen content than the dissolved oxygen in water.

4. Assertion : Symptoms of emphysema develops when a person living on plains ascends and stays on a mountain  
 Reason : Air pressure and partial pressure of oxygen falls with the rise in altitude.
5. Assertion : If there is no air in trachea, it will collapse.  
 Reason : Trachea is having the cartilagenous ring. [AIIMS 1999]
6. Assertion : Inspiration occurs due to muscular relaxation.  
 Reason : During inspiration, the diaphragm and external intercostal muscle contract simultaneously. [AIIMS 1995]
7. Assertion : Severe Acute Respiratory Syndrome (SARS) originated in China.  
 Reason : China is the most populated country of the world. [AIIMS 2003]
8. Assertion : Blood of insects is colourless.  
 Reason : The blood of insect does not play any role in transport of oxygen. [AIIMS 1994]
9. Assertion : Gill-lamellae in aquatic animals help in exchange of gases.  
 Reason : Each gill lamella carries many blood capillaries.
10. Assertion : In mammals, complex respiratory system has developed.  
 Reason : Mammalian skin is impermeable to gases.
11. Assertion : Insects develop a complex system of air tubes called trachea for respiratory purpose.  
 Reason : Exchange through body surface is not possible in insects.
12. Assertion : Aerobic respiration involves the exchange of respiratory gases twice.  
 Reason : Exchange occurs from lung to heart and then heart to lung.
13. Assertion : Carbonic anhydrase is present in the erythrocytes.  
 Reason : In erythrocytes the carbon dioxide combine with water and is transported. [Kerala PMT 2006]

## Answers

### Respiratory organs

1	d	2	a	3	d	4	d	5	d
6	d	7	c	8	d	9	a	10	b
11	a	12	d	13	d	14	a	15	c
16	d	17	a	18	d	19	d	20	d
21	a	22	d	23	c	24	b	25	c
26	d	27	c	28	a	29	c	30	d
31	a	32	b	33	d				

**Pulmonary volumes and capacities**

1	b	2	d	3	b	4	b	5	c
6	d	7	b	8	c	9	a	10	b
11	a	12	d	13	a	14	b	15	c
16	d	17	a	18	a	19	d	20	d
21	a								

**Process of respiration**

1	a	2	a	3	b	4	c	5	a
6	c	7	d	8	c	9	b	10	c
11	c	12	b	13	d	14	a	15	b
16	b	17	c	18	e	19	b	20	a
21	c	22	d	23	b	24	d	25	a
26	b	27	c	28	a	29	b	30	c
31	c	32	a	33	a	34	a	35	a
36	b	37	c	38	b	39	d	40	d
41	e	42	b	43	c	44	c	45	a
46	d	47	b	48	b	49	d	50	b
51	d	52	a	53	c	54	b	55	c
56	a	57	c	58	a	59	d	60	c
61	a	62	c	63	a	64	b	65	c
66	c								

**Control of breathing**

1	a	2	c	3	c	4	c	5	b
6	a	7	a	8	a	9	b	10	b
11	c	12	b						

**Important concepts of respiration**

1	c	2	a	3	d	4	c	5	d
6	b								

**Disorders of respiration system**

1	a	2	c	3	c	4	c	5	c
6	c	7	d	8	d	9	a	10	d
11	d	12	c	13	b	14	d	15	a
16	d	17	b						

**NCERT Exemplar Questions**

1	d	2	d	3	d	4	b	5	a
6	d	7	d	8	b	9	b	10	b
11	b	12	b	13	b				

**Critical Thinking Questions**

1	d	2	b	3	d	4	d	5	d
6	a	7	d	8	c	9	b	10	a
11	a	12	a	13	b	14	b	15	b

16	b	17	a	18	b	19	a	20	c
21	a	22	d	23	b	24	c	25	d
26	a	27	b	28	acd				

**Assertion and Reason**

1	a	2	b	3	c	4	e	5	e
6	e	7	b	8	b	9	a	10	b
11	a	12	c	13	a				

# S

**Answers and Solutions****Respiratory organs**

3. (d) Haemolymph is found in insect blood which is colourless.
7. (c) In forced expiration internal intercostal muscles and some abdominal muscles contract to reduce the volume of thorax.
10. (b) Inside the larynx there are vocal cords. These are two pairs of fold of mucous membrane that extend into the lumen of the larynx from the sides
12. (d) The pharynx provides passage to both air and food.
14. (a) In man, the left lungs has two lobes, superior lobe and inferior lobe, the right lungs has three lobes superior lobe, middle lobe and inferior lobe.
18. (d) Earthworm has a closed circulatory system. Hb dissolved in plasma of blood acts as a respiratory pigment, transporting  $O_2$  to the body tissues.
23. (c) In rabbit, the left lung is divided into two lobes, left anterior and left posterior whereas the right lung has four lobes, anterior azygous, right anterior right posterior and posterior azygous.
24. (b) Each lung is enclosed in two membranes called pleurae. The outer covering is adhered to chest wall and diaphragm and is called parietal pleura. The inner covering membrane, which closely covers the lung, is called visceral pleura
27. (c) Haemocyanin is copper containing pigment. It is respiratory pigment of Prawn. Haemocyanin becomes blue when oxygenated and colourless during deoxygenation.
30. (d) It serves to close the glottis during deglutition thereby preventing entry of food into respiratory tract.
31. (a) Diaphragm has no role in the respiration in frog but in mammals it increase the surface area for respiration.
33. (d) Presence of diaphragm is mammalian character, which is dome-shaped partition that separates the thoracic and abdominal cavities.

**Pulmonary volumes and capacities**

5. (c) Vital capacity of lungs to expire maximum volume of air after a deep inspiration. The largest quantity of air that can be expired after a maximal inspiratory. Vital capacity is equal the sum of the tidal complemental and supplemental air ( $500 + 3100 + 1200 = 4800 \text{ ml}$ ).

9. (a) The volume of air inspired and expired with each normal breath is tidal volume, which is approximately 500 ml.
12. (d) The residual volume is that part of the air in the lung which cannot be exhaled; it represents the remaining volume of lung when forced exhalation of the lung has occurred.

### Process of respiration

1. (a) More active tissue has much lower  $PO_2$ . Therefore much more oxygen is released from oxyhaemoglobin in the active tissue.
3. (b) The gaseous exchange is the simple diffusion of oxygen from alveolar air into the blood and diffusion of  $CO_2$  from blood to alveolar air.
5. (a) Oxygen tends to displace  $CO_2$  so that the curve shifts more to the right.
11. (c) This pump is connected through a tube to an external machine for inflating or deflating it with helium.
13. (d) Nearly 20-25 percent of  $CO_2$  is transported by RBCs, whereas, 70 percent of it is carried as bicarbonates. About 7 percent of  $CO_2$  is carried as dissolved state in plasma.
25. (a) Under a given oxygen concentration in blood, dissociation of oxyhaemoglobin will increase if pH of blood falls.
28. (a)  $O_2$  dissociation curve for haemoglobin is sigmoid in shape.
29. (b) During expiration diaphragm relaxes and becomes dome-shaped thereby reducing intrathoracic volume to pass out the air from body.
31. (c) During pulmonary respiration mouth remains closed all the time whereas nostrils are opened only when air is taken in or passed out i.e. during first stroke of inspiration and second stroke of expiration respectively.
32. (a) In anaerobic respiration pyruvate undergoes two types of incomplete reduction. In one case it results in the production of ethyl alcohol (Yeast) and in other it produces lactic acid (muscles).
38. (b) Bilirubin is an orange pigment that is one of the end product of haemoglobin breakdown in the hepatocyte and is excreted as a waste material in bile.
39. (d) In the form of  $H_2CO_3$  dissolved in plasma and  $NaCO_3$  and  $KHCO_3$  as bicarbonates.
43. (c) A is the alveolar cavity which is the main site of exchange of respiratory gases.
45. (a) Rise in  $CO_2$  concentration is detected by chemosensitive area activates inspiratory centre in Medulla oblongata, which lead to urge of breathing. Role of  $O_2$  concentration is non significant.
47. (b) During normal breathing the respiratory movement in 25 years old is about 16/min.
48. (b) To maintain electrostatic neutrality of plasma, many chloride ions diffuse from plasma into RBCs and bicarbonate ions pass out. The chloride content of RBCs increases when oxygenated blood becomes deoxygenated. This termed as chloride shift or Hamburger shift.
50. (b) Sternohyal and petrohial helps in respiration of frog. Contraction of sternohyal muscle during breathing in frog lowers floor of oral cavity. While contraction of petrohial muscle during breathing in frog raises the floor of buccal cavity.
53. (c) 7% of  $CO_2$  is transported in dissolved form in the plasma, 23% as carbaminohaemoglobin and 70% in the form of bicarbonates.
54. (b) Our tissues are able to utilise only 25% of  $O_2$  carried by arterial blood. Our venous blood is still 75% saturated with  $O_2$ . This  $O_2$  acts as a reserve during muscular exercise.
57. (c) Respiration is the process of oxidation by which food material are oxidized and produce  $CO_2$  and water as waste product.
59. (d) Surfactant is a lipoprotein secreted by surfactant secreting cells, which form part of alveolar epithelium. This tends to reduce the surface tension of fluid lining the alveoli and thus facilitates lung expansion and also maintains the stable size of the alveoli.
60. (c) In the form of phosphate bond energy.
63. (a) During inspiration the diaphragm and external intercostal contract simultaneously. This moves the lateral thoracic walls outward and upward.
66. (c)  $PO_2$  in Alveoli is 104, while in oxygenated blood, it is 95.

### Control of breathing

1. (a) Tidal volume is the volume of air breathed in and out during normal respiration and is equal to about 500 ml or 0.5 l
3. (c) Tidal volume is the volume of air inspired or expired with each breath. This is about 500 ml in an adult person.
6. (a) Because the respiratory centres are located in the medulla oblongata and pons varoli in the hind brain.
8. (a) Breathing is controlled by pneumotaxic and apneustic centres in pons varoli and expiratory and inspiratory centres in medulla oblongata.
10. (b) A chemosensitive area located close to the respiratory centre in medulla is highly sensitive to changes in  $PCO_2$  or pH of the blood.

**Important concepts of respiration**

3. (d) Hemoglobin, an iron containing red pigment is responsible for transport of  $O_2$  and  $CO_2$  in human blood.
4. (c) The affinity of haemoglobin for CO is approximately 210 times greater than  $O_2$ .
6. (b) The oxygenated blood from two lungs is collected by right and left pulmonary veins, which unite to form a common pulmonary vein (Pulmocutaneous vein) which open directly into the left auricle, on the dorsal side

**Disorders of respiration system**

1. (a) Rate of  $O_2$  supply by lungs into muscles falls down during active work or in exercise. Muscles accumulate lactic acid and slowly breathing becomes hard so as to increase  $O_2$  intake in lungs. This stage is called oxygen debt.
2. (c) Because plants release pollen grain a fix time and it is generally March-April or Aug. – Sep.
8. (d) Cyanosis is blueness of skin and occurs due to large amount of deoxygenated haemoglobin in cutaneous vessels.
12. (c) Oxygen toxicity develops when pure oxygen is breathed in for a prolonged period. This is formed due to progressive failure of ventilation of lungs.
13. (b) Diabetic patient shows low R.Q. due to the increased dissimilation of fats and decreased dissimilation of carbohydrates.
16. (d) Emphysema is the respiratory disorder in which the septa between the alveoli are destroyed and much of the elastic tissue of the lungs is replaced by connective tissue. It is generally caused by a long term irritation. Air pollution, occupational exposure to industrial dust and cigarette smoke are the most common irritants

**Critical Thinking Question**

1. (d) Some snakes have only one bronchus and the right lung.
2. (b) In mammalian lungs each alveolar duct ends in a passage, called atrium, which leads into a number of rounded alveolar sacs. Each alveolar sac is studded with a large number of air sacs or alveoli. Alveoli are the sites of respiration.
3. (d) Syrinx is a sound producing organ in birds.
4. (d) The respiratory centres that control the breathing mechanism are present in medulla oblongata. These respiratory centres are expiratory centre and inspiratory centre.
5. (d) The number of alveoli in human lungs has been estimated to be approximately 750 million, exposing a surface area of nearly  $100 m^2$ .

7. (d) The nerve impulse ordered by respiratory centre passes through vagus nerve to the intercostal muscles and diaphragm and regulates respiration. The respiratory centres are scattered in brain stem and are constantly giving off rhythmically stimuli to the respiratory muscles in virtue of their inherent rhythm causing inspiration and expiration.
9. (b) Every 100 ml of blood receives an average 3.7 ml of  $CO_2$  from tissues.
15. (b) Carbon monoxide has 210 times more affinity with haemoglobin as compared to  $O_2$  and forms a stable compound
18. (b) Due to direct chemical control on respiratory centres,  $CO_2$  stimulates respiratory centres in CNS.
19. (a) At high altitude,  $PO_2$  of alveolar air falls because of low  $O_2$  tension of tissues. So,  $O_2$  is absorbed very quickly from alveoli, thus, increasing breathing rate. Heart beat also increases to supply required amount of  $O_2$  to tissues.
20. (c) COHb is a stable compound formed by the combination of carbon monoxide and haemoglobin. It has more affinity than oxygen.
21. (a) Due to absence of respiratory pigment.
22. (d) Deep breathing rises the  $O_2$  level of the blood. By excess formation of oxyhaemoglobin the acidity of blood increases. To control it, more of free  $CO_2$  changes into bicarbonates and the free  $CO_2$  level in the blood decreases. So due to lack of stimulant for inspiratory centre cessation of breathing takes place, after some time  $O_2$  is consumed by the tissues and rise in  $CO_2$  stimulates breathing again.
23. (b) To maintain electrostatic neutrality of plasma, many chloride ions diffuse from plasma into RBCs and bicarbonate ions pass out. The chloride content of RBCs increase when oxygenated blood become deoxygenated. This is termed as chloride shift or Hamburger phenomenon.
25. (d) This process occurs through nares and mouth and gullet are kept closed during the process.
28. (acd) Silicosis is an occupational lung disease that causes progressive respiratory failure and death. ADH is synthesized from hypothalamic nuclei and are responsible for water absorption by nephron. Myasthenia gravis is an autoimmune disorder mediated by antibodies.

## Assertion and Reason

1. (a) In most animals, tissue oxidation are carried out by aerobic respiration. But sometimes in aerobically respiring animals, anaerobic metabolism take place in certain tissues like skeletal muscles which do not immediately get as much oxygen as is necessary for their acid anaerobically from glucose during vigorous movements.
2. (b) Coughing and sneezing are necessary to take place because these reactions serve to keep the air passages free from foreign matter. Coughing is a reflex action under nervous control. The minute receptors found in the wall of trachea, bronchi, bronchioles and alveoli are highly sensitive to foreign matter (smoke, dust etc.) Like coughing, sneezing is also a reflex action triggered because of irritation to nasal passages. In this, sensory impulses travel from nasal passages to the medulla through trigeminal nerves. The reaction involves the same series of events as in cough reflex, but the air explodes out both through nose and mouth, expelling the foreign matter from nasal passages.
3. (c) Although atmospheric air contains far more oxygen content than the water (air contain 21% oxygen and water contains 0.5-0.9% oxygen by volume depending on the temperature), still most fish when out of water die of suffocation due to lack of oxygen. When fish is taken out of water the gills stick together thereby reducing the surface area. Reduced surface area lowers gas exchange so death ensues.
4. (e) When a person living on plains ascend and stays on a mountain above 8000 feet from the sea level, he develops symptoms of mountain sickness which includes breathlessness, headache, dizziness, irritability, nausea, vomiting, mental fatigue and a bluish tinge on the skin, nails and lips.  
We know that with the rise in altitude, the barometric pressure and consequently the partial pressure of oxygen falls in the atmospheric air. This lowers the alveolar partial pressure of oxygen which causes reduction in the diffusion of oxygen from the alveolar air to the blood. So oxygenation of blood is decreased progressively, which produces the symptoms of mountain sickness, Emphysema.
5. (e) There is no air in trachea, it does not collapse due to the presence of C-shaped narrow cartilaginous ring or discs.
6. (e) Inspiration is the result of muscular contraction. The diaphragm and external intercostal muscle contracts simultaneously. The lateral thoracic wall moves outward and upward
7. (b) The world health organization (WHO) reported China as the origin place of SARS. Several other countries have reported SARS cases after travel to China and its nearby areas/countries in Asia or close contact with a person affected with SARS. Microbiologists of Hongkong Central University initially detected a virus metapneumovirus and identified as corona virus causative agent of SARS. It is very known fact that the China is the most populated country. This fact cannot be correlated with SARS
8. (b) Blood is colorless in insects. Insects have tracheal respiration. It is carried on by an extensive system of inter-communicating tubes called trachea.
9. (a) Gills are the main respiratory organs of aquatic animals. Each gill bears rows of comb-like, soft, thin gill-filament, each gill-filament bears many flat, parallel membrane-like gill-lamellae. Each gill lamella carries many blood capillaries. Water taken through the mouth, is made to flow from the pharynx in a single direction between the gill lamella. Blood flows in the capillaries of gill-lamella in a direction opposite to the flow of water over the lamellar surfaces. This greatly helps in the gaseous exchange across the lamellar membrane between the capillary blood and the flowing water.
10. (b) Mammalian skin is impermeable so that water loss through it is minimized. But mammals need far more oxygen to maintain their high metabolic rates than lower animals; so they need a more extensive respiratory surface. Thus a complex respiratory system has evolved in mammals to meet this need. The mammalian respiratory system consists of the nasal cavity, nasopharynx, larynx, trachea, bronchi, bronchiole and lungs.
11. (a) As the integument of insect is thick and impermeable to minimize loss of body water, they can not carry out gas exchange through their body surface. To overcome this difficulty they have developed a complex system of air tubes called trachea to reach the air directly near the tissue cells. Each trachea communicates with the exterior through openings in the body wall.
12. (c) Aerobic respiration involves the exchange of respiratory gases at two places in multicellular animals-one between the body surface and surrounding medium, the other between the individual cells and the extra cellular fluid. Lungs are involved in the first step of exchange, but not the heart.
13. (a)



## Breathing and Exchange of Gases

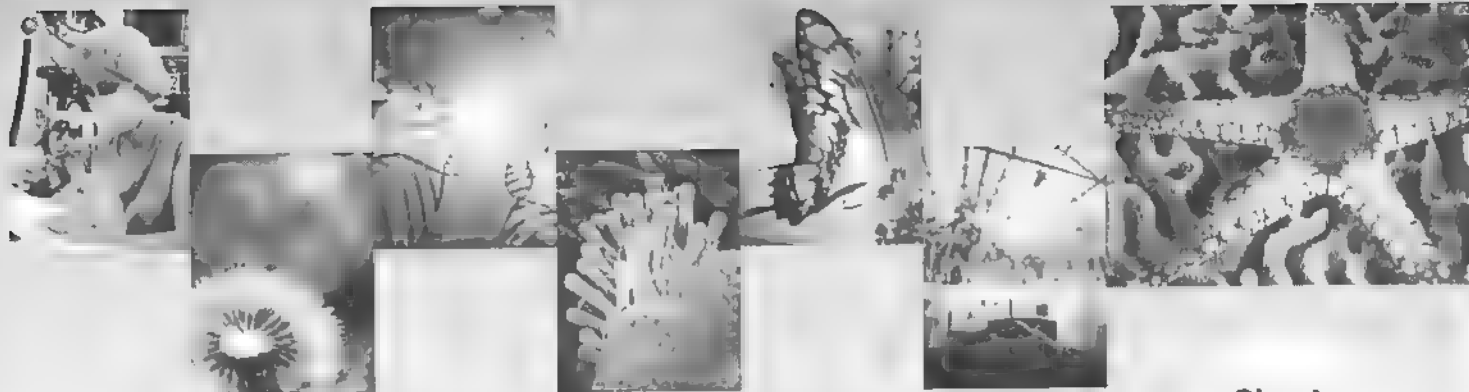
## Self Evaluation Test

1. Voice in mammal produced [MP PMT 2000]
  - (a) By syrinx (b) By bronchus
  - (c) During inhalation (d) During exhalation
2. In vertebrate blood which respiratory pigment is the carrier of oxygen to the tissues. [MP PMT 1998]
  - (a) Plasma (b) Lymphocytes
  - (c) Leucocytes (d) Haemoglobin
3. The haemoglobin of a human foetus [CBSE PMT 2008]
  - (a) Has only 2 protein subunits instead of 4
  - (b) Has a higher affinity for oxygen than that of an adult
  - (c) Has a lower affinity for oxygen than that of the adult
  - (d) Its affinity for oxygen is the same as that of an adult
4. Which of the following disease is associated with lungs [DPMT 1993]
  - (a) Bronchitis (b) Pneumonia
  - (c) Asthma (d) All the above
5. What is the total vital capacity of lungs in man [MP PMT 1997; BVP 2000]
  - (a) 500 ml (b) 2,000 ml
  - (c) 4,600 ml (d) 5,800 ml
6. Which one of the following disorders and characteristic is correctly matched [AIIMS 2009]
  - (a) Cystic fibrosis – Production of thick mucous that clogs airways
  - (b) Sickle cell anaemia – Brain deterioration beginning at months of age
  - (c) Achondroplasia – Extra fingers or toes
  - (d) Huntington's disease – Skeletal, eye and cardiovascular defects
7. Pick the correct statement [Kerala PMT 2010]
  - (a) The contraction of internal intercostal muscles lifts up the ribs and sternum
  - (b) The RBCs transports oxygen only
  - (c) The thoracic cavity is anatomically an air tight chamber
  - (d) Healthy man can inspire approximately 500 ml of air per minute
  - (e) During expiration, the intrapulmonary pressure is slightly below the surrounding atmospheric pressure
8. Which mammal lacks true vocal cords
  - (a) Monkey (b) Elephant
  - (c) Hippopotamus (d) Man
9. The haeme-protein complexes which act as oxidising agents are known as [Kerala PMT 2009]
  - (a) Haemoglobin (b) Myoglobin
  - (c) Chlorophyll (d) Cytochrome
10. How many molecules of oxygen are bound to one molecule of haemoglobin [NCERT; MP PMT 1997; RPMT 2005; Odisha JEE 2009; AFMC 2010]
  - (a) 1 (b) 2
  - (c) 3 (d) 4
11. Read the following statements and select the correct one [Kerala PMT 2009]
  - (a) The  $H^+$  released from carbonic acid combines with haemoglobin to form haemoglobinic acid
  - (b) Oxyhaemoglobin of erythrocytes is alkaline
  - (c) More than 70% of carbon dioxide is transferred from tissues to the lungs in the form of carbamino compounds
  - (d) In a healthy person, the haemoglobin content is more than 25 gms per 100 ml
  - (e) In lungs, the oxygen from the alveolus reaches the blood through active transport
12. Oxygen content reduction makes the glycolyse (glycogenesis) intensity increased due to [AIIMS 2010]
  - (a) Increase of ADP concentration in cell
  - (b) Increase of  $NAD^+$  concentration in cell
  - (c) Increase of ATP concentration in cell
  - (d) Increase of concentration of peroxides and free radicals
13. Amount of air exchanged in breathing can be measured with a [NCERT]
  - (a) Spherometer (b) Barometer
  - (c) Spirometer (d) Sphygmomanometer
14. It is much easier for a small animal to run uphill than for a large animal, because [NEET (Phase-I) 2016]
  - (a) It is easier to carry a small body weight
  - (b) Smaller animals have a higher metabolic rate
  - (c) Small animals have a lower  $O_2$  requirement
  - (d) The efficiency of muscles in large animals is less than in the small animals

## S Answers and Solutions

1	d	2	d	3	b	4	d	5	c
6	a	7	c	8	c	9	d	10	d
11	a	12	a	13	c	14	b		

10. (d) One molecule of the haemoglobin has 4 haem groups and each of them is capable of taking up one molecule of  $O_2$ .
13. (c) Spirometry is the process of recording the changes in the volume movement of air into and out of lung and the instrument used for the purpose is called spirometer or respirometer



## Chapter 5.3

# Body Fluids and Circulation

This system is concerned with the circulation of body fluids to distribute various substances to various body parts.

### Functions of Circulatory System

(1) Transport of various substances such as nutrients, waste products, respiratory gases, metabolic intermediates (Such as lactic acid from muscle to liver), vitamins, hormones etc.

(2) Regulation of body pH by means of buffer, body temperature homeostasis, water balance etc.

(3) Prevention of diseases by means of antibodies and antitoxins.

(4) Support or turgidity to certain organs like penis and nipples.

### Types of Circulation

Circulatory system in various groups of animals can be classified as follows :

(1) **Intracellular circulation** : Occurs inside the individual cells where the distribution of substances is through cyclosis of cell cytoplasm. Example – Protozoans.

(2) **Extracellular circulation** : When the distribution of the substances occurs inside the body through extracellular or intracellular fluids. This is of following types –

(i) **Extra organismic circulation** : Canal system in porifera, water vascular system in Echinoderms and gastrovascular system in coelenterates.

(ii) **Intra-organismic circulation** : It involves circulation of body fluids. It is of following types –

(a) **Parenchymal circulation** : In platyhelminthes, the fluid filled spaces present in the mesodermal parenchyma tissue between body wall and internal organs are used in the distribution of substances.

(b) **Coelomic circulation** : Coelomic fluid is concerned with the transport of substances. Example – pseudocoelomic fluid in the roundworms and haemolymph in Arthropods.

(c) **Blood vascular system** : It contains blood and a pumping structure (heart) for circulation of materials inside the body. It is open circulatory system and closed circulatory system.

**Table : 5.3-1 Differences between open and closed circulatory system**

S.N.	Open circulatory system	Closed circulatory system
1.	In open circulatory system blood flows through large open spaces and channels called lacunae and sinuses among the tissues.	In closed circulatory system blood flows through a closed system of chambers called heart and blood vessels.
2.	Tissues are in direct contact with the blood.	Blood does not come in direct contact with tissue.
3.	Blood flow is very slow and blood has very low pressure.	Blood flow is quite rapid and blood has a high pressure
4.	Exchange of gases and nutrients takes place directly between blood and tissues.	Nutrients and gases pass through the capillary wall to the tissue fluid from where they are passed on to the tissues.
5.	Less efficient as volume of blood flowing through a tissue cannot be controlled as blood flows out in open space.	More efficient as volume of blood can be regulated by the contraction and relaxation of the smooth muscles of the blood vessels.
6.	Open circulatory system is found in higher invertebrates like most arthropods such as prawn, insects, etc., and in some molluscs (snails, clams, oyster).	Closed circulatory system is found in echinoderms, some molluscs, (squids) annelids and all vertebrates.
7.	Respiratory pigment, if present, is dissolved in plasma; RBCs are not present	Respiratory pigment is present and may be dissolved in plasma but is usually held in RBCs.



## Blood circulation in vertebrates

Blood circulation was discovered by William Harvey. In case of vertebrates, blood circulation is of closed type, which can be grouped into two categories :

(1) Single circulation

(2) Double circulation

**Table : 5.3-2 Differences between single and double circulation**

S.N.	Single circulation	Double circulation
1.	Blood flows only once through the heart in a complete cycle. Auricle → Ventricle Tissues ← Gills	Blood flows in two circuit pulmonary and systemic. Pulmonary vein Right auricle → Right ventricle → Pulmonary artery → Lungs Left auricle → Left ventricle → Dorsal aorta → Tissues → Venacava → Right auricle
2.	Heart pumps only deoxygenated blood, hence called Venous Heart.	Heart pumps both deoxygenated and oxygenated blood to lungs and body respectively, hence called arteriovenous heart.
3.	Blood is oxygenated in gills	Blood is oxygenated in lungs.
4.	Less efficient as gill capillaries slow down the blood flow. So, the body receives blood at a low pressure which decreases the rate of $O_2$ supply to the cells i.e. keeps the metabolic rate low.	More efficient as blood flows at higher pressure, especially in birds and mammals, which increases the rate of food and $O_2$ supply to the cells and also rapid removal of wastes from them i.e. provides a higher metabolic rate
5.	Found only in fishes, petromyzon.	Found in dipnoi, amphibians, reptiles, birds and mammals.

Double circulation in mammals can be divided into three parts :

(i) **Cardiac circulation** : The amount of blood present in the heart. Its value is 8%.

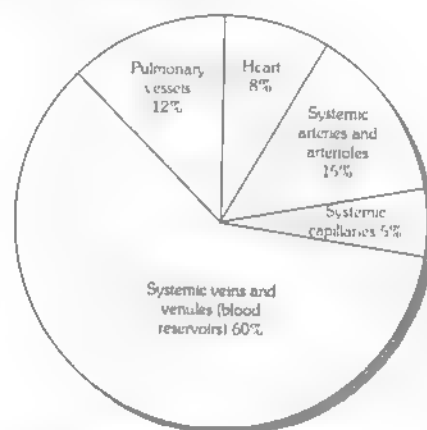
(ii) **Pulmonary or lesser circulation** : The amount of blood present in the surrounding of lungs and pulmonary blood vessels. Its value is 12%.

(iii) **Systemic or greater circulation** : The amount of blood which circulates in the rest part of the body. Its value is 80%. It can be divided into three parts –

Arterial circulation – 15%

Capillary circulation – 5%

Venous circulation – 60%



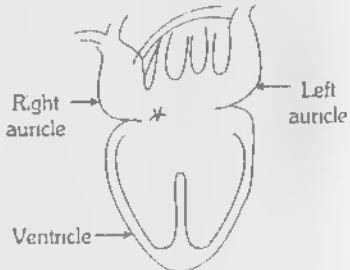
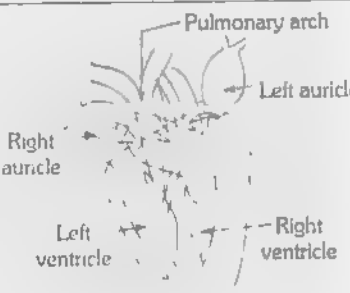
**Fig : 5.3-1 Distribution of blood volume in different part of circulatory system**

## Heart

The form, structure and function of heart exhibits much variation. The characteristics of heart of fishes, amphibians, reptiles, birds and mammals is presented in the following table.

**Table : 5.3-3 Heart of vertebrates**

S.No.	Class of vertebrates	Characteristics	Example	Diagram
1.	Pisces (= Branchial heart), Cyclostomata	Thick, muscular, made of cardiac muscles, has two chambers (i) auricle and (ii) ventricle. The heart is called venous heart since it pumps deoxygenated blood to gills for oxygenation. This blood goes directly from gills to visceral organs (single circuit circulation). A sinus venosus and conus arteriosus is present. Lung fishes have only one auricle and one ventricle	Labeo Scoliodon	
2.	Amphibians, Lung fish	Heart consists of (i) Two auricles (ii) Undivided ventricle (iii) Sinus venosus (iv) Truncus arteriosus (conus + proximal part of aorta) Right auricle receives blood from all the visceral organs (deoxygenated) via precaval and post	Frog Toad Neoceratodus or Dipnoi	

		caval. Pulmonary artery carries deoxygenated blood to lungs for oxygenation. This blood returns to left auricle via pulmonary vein (Double circuit circulation) (v) S.A. node in sinus venosus (vi) Truncus arteriosus divided into synangium, pylangium		
3.	Reptiles	Heart consists of : (i) Left and right auricle (ii) Incompletely divided ventricle (Ventricle in crocodiles, gavialis, and alligator is completely divided) (iii) Sinus venosus (iv) Conus arteriosus divided into right systemic, left systemic and pulmonary arch. (Double circulation) (v) Foramen panizzae at crossing of right-left systemic arch. (vi) Only SA node in right auricle	Lizards Snakes Turtles	
4	Aves	Exhibit double circulation Heart consists of (i) Left and right auricle (ii) Left and right ventricle (iii) Complete separation of arterial and venous circulation (iv) Only right systemic arch is present (v) Sinus venosus and truncus, arteriosus absent (vi) Two pace maker SA node and AV node (vii) Mitral valve present.	Pigeon	
5	Mammals	Same as bird except that mammals have left systemic arch	Rabbit, man	

**Shape and position :** Reddish, roughly conical, highly muscular, mesodermal hollow organ of the size of one's fist. Its average weight in males is about 300 gm. and in females about 250 gm. It lies behind the sternum in the mediastinum space of thoracic cavity in between the two lungs. The broader base faces upward and backward. The narrower apex is directed downward, forward and slightly towards left, lying between 5<sup>th</sup> and 6<sup>th</sup> ribs and rests on the diaphragm. The heart is about 12 cm (5 inch) long, 9 cm (3.5 inch) wide and 6 cm (2.2 inch) thick.

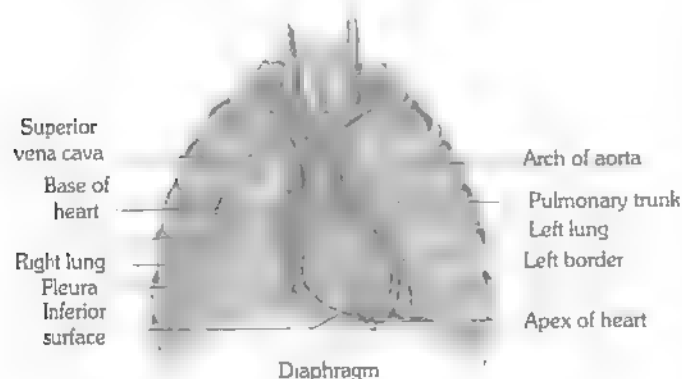
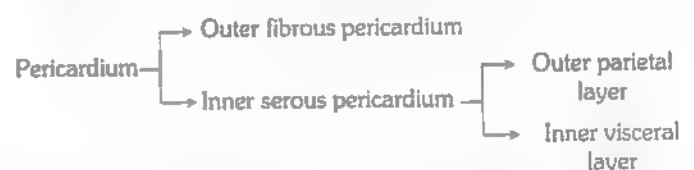


Fig : 5.3-2 Position of heart in our chest cavity

**Protective covering :** Heart is enclosed in a tough, 2 layered fibroserous sac, the pericardium. The outer layer is non-distensible fibrous pericardium and inner layer is thin serous pericardium which further consists of outer parietal layer (attached to fibrous pericardium) and inner visceral layer (adhered to the heart).



Between the parietal and visceral layers, occurs a narrow potential space, the pericardial cavity which is derived from coelom and is filled with serous pericardial fluid for frictionless movement and protection from shock and mechanical injury.

**Histology :** The heart wall consists of connective tissue, blood vessels and cardiac muscle fibres in 3 different layers – Epicardium, Myocardium and Endocardium.

(1) **Epicardium** : The outermost epicardium, also called visceral layer of the serous pericardium, is the thin, transparent outer layer of the wall. It is composed of mesothelium and connective tissue. Visceral pericardium, is joined to the myocardium by connective tissue.

(2) **Myocardium** : Middle, highly vascular layer, composed of cardiac muscle fibres are joined together by intercalated disc. The connective tissue in myocardium acts as cardiac skeleton. Myocardium is thickest where the endocardium is thinnest.

(3) **Endocardium** : Innermost layer lining the cavity of heart and consisting of endothelium of squamous cells resting on thin basement membrane of loose connective tissue

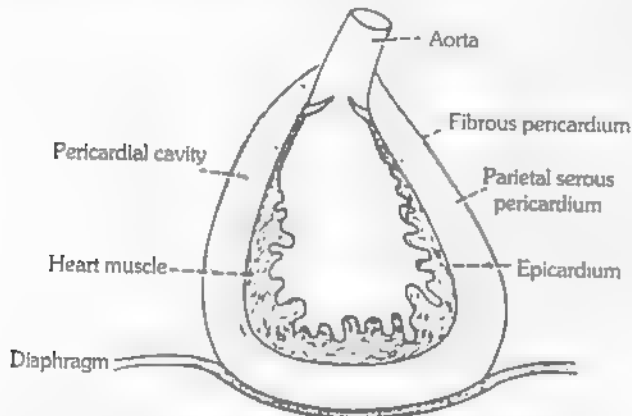


Fig : 5.3-3 Diagram to show the layers of the pericardium

**External structure** : Human heart is 4-chambered and is divided by septa into two halves – right and left. Each half has one darker, thin walled auricle in the broader upper region and one lighter, thick-walled ventricle in the narrower lower region.

Sinus venosus and conus/truncus/bulbus arteriosus are accessory chambers in the heart of lower vertebrates (fishes and amphibians). In rabbit, sinus venosus is formed in the embryo but later it becomes a part of wall of right auricle.

In frog, sinus venosus spreads upon most of the dorsal side of heart and conus arteriosus lies obliquely upon the ventral surface of right atrium.

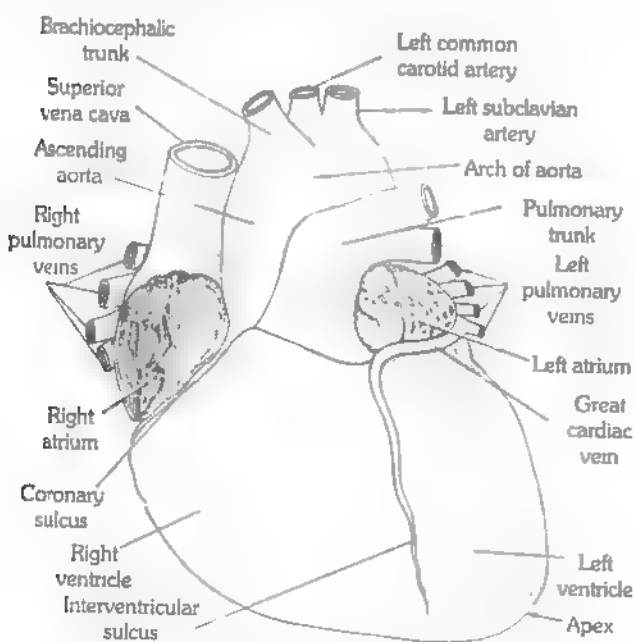


Fig : 5.3-4 External features of human heart

### Internal structure

(1) **Auricles** : Atria are thin walled. They act as reservoirs for blood entering the heart. Right auricle is bigger than left auricle and both are separated by a myomembranous partition called Interatrial or interauricular septum. During embryonic stage, at the place of this septum, there are present septum primum and septum secundum having a gap (aperture) called foramen ovale between them. From the opening of inferior vena cava upto foramen ovale, there is a flap called Eustachian flap which prevents the blood in the foetal heart go to lungs because in foetal life, lungs are not functional purification of blood is done by placenta.

At the time of birth, there is closure of foramen ovale but there remains depression on posterior part of the right surface of interauricular septum in rabbit. In man this depression is present on both the side because of least regenerative power in human being. The depression towards right atrium is called fossa ovalis and depression towards left atrium is called fossa lunata.

The inner surface of auricles is smooth. A network of muscular ridges called musculi pectinati or trabeculi pectinati occurs internally in the region of the auricular appendages and give comb like appearance.

❑ **PFO (Patent Foramen Ovale) or septal defect** : In case there is no closure of foramen ovale, then disease is called PFO. In this condition, there is mixing of blood after birth which gives bluish appearance to the body called as Cyanosis. Such child is called Blue Baby.

(2) **Ventricles** : The right and left ventricles are demarcated by an Interventricular septum which is obliquely curved towards right, so that the left ventricle is larger than right one. However, the cavity of left ventricle is relatively smaller and nearly circular because the myocardium of left ventricle is 3 times thicker than right ventricle whose cavity is larger and somewhat crescentic.

The walls of the ventricles are internally raised into a number of thick, muscular, column shaped projections called columnae carnae or trabecular carnae; and a few large muscular elevations called papillary muscles or musculi papillares which are 3 in right ventricle and 2 in left ventricle. These muscles act as anchors for chordae tendinae.

Numerous, strong, inelastic thread like tendons are present in the mammalian heart but absent in frog.

❑ **Regurgitation** : If there is weakening of papillary muscles or breaking of chordae tendinae, then AV valves revert into auricles. So, blood goes in opposite direction, it is called regurgitation. Sometimes, there is narrowing of valves. So, there remains gap between the valves which causes regurgitation.

❑ **Moderator band** : Right ventricle contains a prominent muscular trabeculum called moderator band which extends from the interventricular septum to anterior papillary muscle.

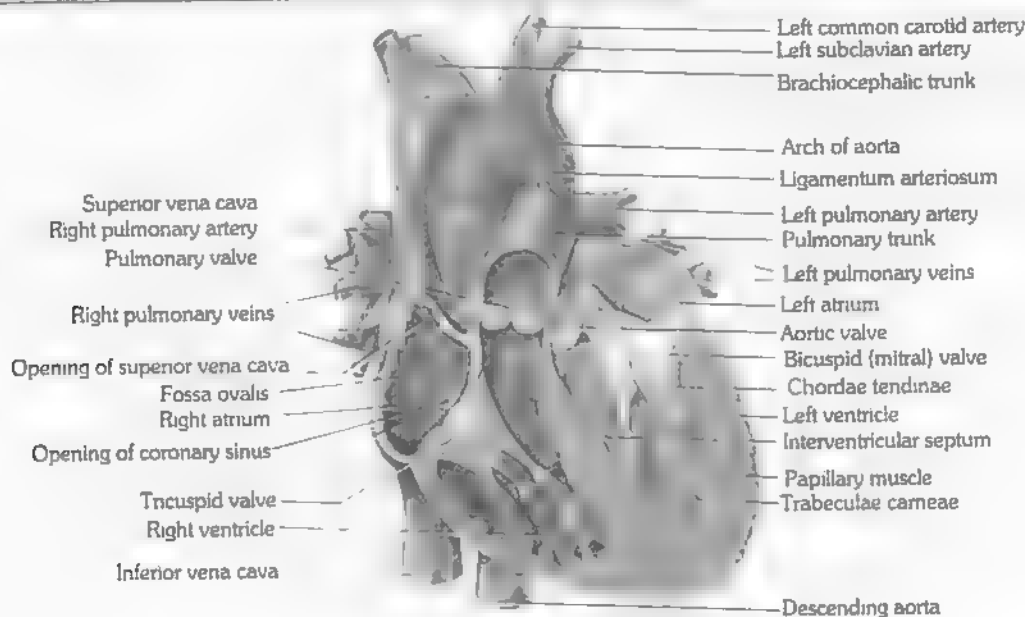


Fig : 5.3-5 Internal anatomy of human heart

**Major blood vessels associated with heart :** The blood vessels that enter or leave the heart are called Great Blood Vessels.

(1) **Superior vena cava or precaval :** Brings deoxygenated blood from head and upper parts of the body into the right auricle through an opening which is single in human and cat and two in rabbit as there are 2 precavals – right and left in rabbit.

(2) **Inferior vena cava or post caval :** Drains deoxygenated blood from middle and lower parts of the body into the right auricle through a single opening which is bordered by a membranous, falciform fold which is a remnant of the foetal valve of Eustachian.

(3) **Coronary sinus :** Returns deoxygenated blood from heart wall into right auricle through a single opening.

(4) **Pulmonary vein :** Four pulmonary veins, two from each lung, carry oxygenated blood from the lungs and open into the left auricle through four openings. In rabbit, the pulmonary veins open in the left auricle through 2 openings.

(5) **Pulmonary aorta/arch :** Arises from upper left corner of right ventricle through a single opening and divides into right and left pulmonary arteries which carry deoxygenated blood to the lungs for oxygenation.

(6) **Systemic aorta :** Arises from upper right corner of left ventricle through a single opening and has 3 regions – ascending aorta, arch of aorta and descending aorta. It distributes oxygenated blood to various body parts except lungs.

□ **Ligamentum arteriosum :** During foetal life, because the lungs are non-functional hence blood of pulmonary aorta comes into systemic aorta through a small duct called ductus botalli or ductus arteriosus soon after birth, deposition of elastin fibre blocks this duct, forming a new structure called ligamentum botalli or ligamentum arteriosum.

□ **PDA (Patent Ductus Arteriosus) :** If the ligamentum arteriosus remains open, the condition is called PDA. In this case, there is mixing of blood which leads to blue baby.

**Valves :** Various membranous structure in a hollow organ or passage that temporarily closes in order to permit flow of blood in one direction only

(1) **Eustachian valve :** Present on the opening of inferior vena cava (post caval) in the right auricle in rabbit, whereas in human, the vestige of eustachian valve is present over the opening of post caval vein. It allows the passage of blood in right auricle.

(2) **Haversian valve :** Present in human but absent in rabbit. It is present over the opening of precaval vein and allows the passage of blood in right auricle.

(3) **Thebesian or coronary valve :** Present over the opening of coronary sinus in right auricle in mammals and allows the passage of blood in right auricle.

(4) **Right A.V. valve or Tricuspid valve :** Present between right auricle and right ventricle. It consists of 3 membranous flaps or cusps.

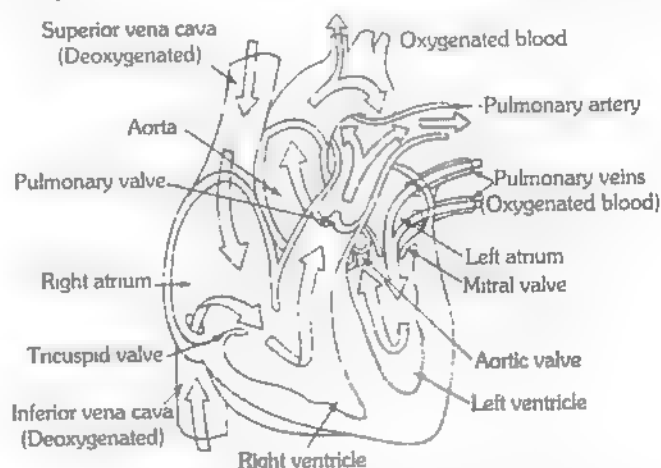


Fig : 5.3-6 Path of blood through the heart

(5) **Left A.V. valve or Bicuspid or Mitral valve :** Present between left auricle and left ventricle. It consists of 2 flaps or cusps. The bicuspid valve resembles mitre or topi of bishop, hence, also called as Mitral valve.

(6) **Semilunar valves** : At the base of pulmonary arch and systemic aorta, three membranous, pocket-shaped flaps called semilunar valves are present. They allow the passage of blood from ventricles to respective blood vessels, but prevent the return of blood.

**Nodal tissue** : The nodal tissue consists of the following –

(1) **Sinu-auricular or S.A. node** : Also called as pacemaker, node of Keith and flask, heart of heart, brain of heart, pulsation centre. It is located in the right wall of right atrium below the opening of superior vena cava. This is the place where sinus venosus is incorporated in the wall of right atrium in the embryo. S.A. node is the main tissue of heart and has highest degree of autorhythmicity (generates beating impulse at the rate of 70-80 times/minute) but least conductivity. The rhythmic impulses produced are called as Sinus rhythmia. In frog S.A. node is present in sinus venosus

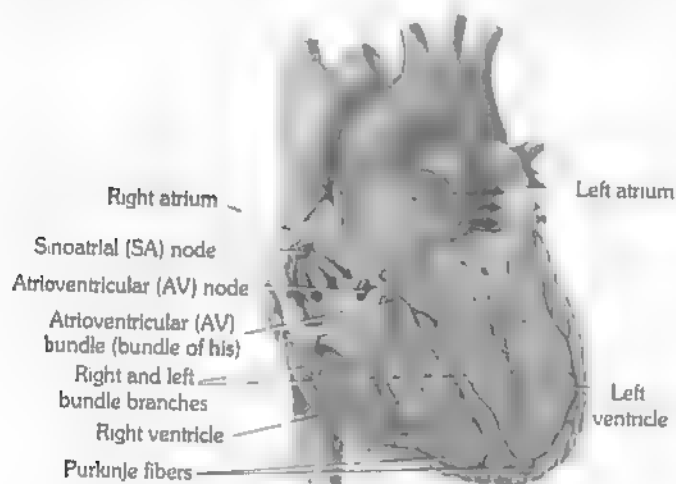


Fig : 5.3-7 Conducting system of rabbit's heart (ventral view)

(2) **Atrio-ventricular node or A.V. node** : Also called reserve pacemaker, node of Tawara and Aschoff. Discovered by Lewis Kent. It lies in the right atrium near the junction of interauricular and interventricular septum close to the opening of coronary sinus. It is concerned with the conduction of cardiac impulses generated by S.A. node, but it can also generate the impulse at the rate of 40-60/minute. These impulses produced are rhythmic and called nodal rhythmia. In frog, A.V. node is absent.

(3) **Bundle of His or A.V. bundle** : Discovered by His. It arises from A.V. node, descends in the interventricular septum and bifurcates into two branches innervating the wall of right and left ventricle respectively. The myocardium of atria and ventricles are discontinuous and this bundle is the only muscular connection between the two. It is concerned with the conduction of impulse from atria to the tip of ventricle but can also generate impulse at the rate of 35-40/minute. The impulses produced are non-rhythmic.

(4) **Purkinje fibres** : Numerous, modified muscle fibres which act as sympathetic nerve fibres. They arise from branches of bundle of His and provide impulse to myocardium of ventricles. They can also generate non-rhythmic impulse at a rate of 30-35/minute.

**Working of nodal tissue** : S.A. node spontaneously initiates a wave of contraction which is conducted along the tracts of special muscle fibres called internal pathways over both the auricles at a rate of 1m/sec. The impulse generated travels first in the right atrium than in left atrium. So, right atrium contracts first but the contraction ends simultaneously in both atria. As the musculatures of atria and ventricles are discontinuous and are separated by a septum of fibrous connective tissue, called annular pad in mammals, the wave of contraction is received by A.V. node from myocardium of atria and is provided to bundle of His. The impulses reach the A.V. node about 0.03 seconds after their origin from S.A. node. The A.V. node generates a fresh wave of contraction which passes over both the ventricles along the bundle of His and its ramifications at the rate of 1.5 to 4 m/sec. The Purkinje fibres bring about the contraction of ventricles from the apex of heart which passes quickly towards the origin of pulmonary and systemic arches forcing blood into them.

S.A. node not only acts as pacemaker but also establishes the basic rhythm at which the heart beats. In case of degeneration of S.A. node, A.V. node can generate impulse but it will lead to abnormal beating. The failure of atrial impulse to pass into ventricles for a few seconds to few hours is called ventricular escape or Stokes-Adams syndrome leading to delayed pick up of heart beat. In such conditions, artificial pacemaker (Lithium Battery) is placed underneath the patient's chest.

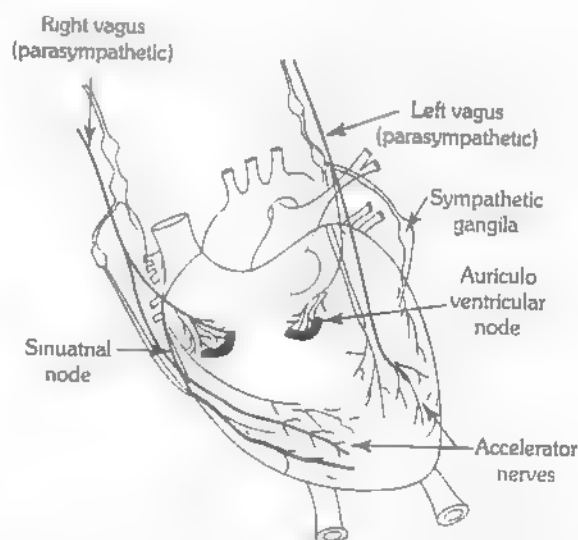


Fig : 5.3-8 Innervation of human heart by autonomic nerves

❑ **Ectopic pacemaker** : If any cardiac muscle other than the conducting tissue (nodes) generates impulse, then extra beats are heard. Such muscles are called Ectopic pacemaker.

In mammals, conducting system of the heart has S.A. node, A.V. node and complicated system of conducting fibres. But in frog, it has only S.A. node and system of conducting fibres is simple.

**Heart beat** : The spontaneous and rhythmic contraction and relaxation of the heart to pump out and receive blood to and from the body is called Heart beat. Depending upon the nature of control of the heart beat, hearts are of 2 types – Neurogenic and Myogenic or autorhythmic.

**Table : 5.3-4 Differences between Neurogenic heart and Myogenic heart**

S. No.	Neurogenic heart	Myogenic heart
1.	The heart beat is initiated by a ganglion situated near the heart.	The heart beat is initiated by a patch of modified heart muscle.
2.	The impulse of contraction originates from nervous system.	The impulse of contraction originates itself in the heart.
3.	The heart normally stops beating immediately after removal from the body. Therefore, heart transplantation is not possible	The heart removed from the body continues to beat for some time. Therefore, heart transplantation is possible.
4.	Examples : Hearts of some annelids and most arthropods	Examples : Hearts of molluscs and vertebrates

**Origin and conduction of heart beat :** Initiation of heart beat is under special bundles of cardiac muscles called nodal tissue or autorhythmic cells. They act as pace maker so setting the rhythm for the entire heart and they form conducting system.

**Heart rate :** Heart beat/minute or number of cardiac cycles/minute. Females have higher heart rate than males.

Normal heart beat rate → Rhythmia

Abnormal heart rate → Arrhythmia

Decrease in heart rate → Bradycardia

Increase in heart rate → Tachycardia

#### Heart rate in some animals

Elephant – 29/min.

Human – 70-80/min.

Foetus (human) – 140-150 / min.

New born baby – 115-130/min.

Horse – 35-40/min

Rat – 300-500/min.

Frog – 64/min.

Rabbit – 200/min.

**Regulation of heart beat :** The centre controlling the heart rate (cardiac centre) is present in medulla oblongata of brain and possess chemoreceptors sensitive for  $\text{CO}_2$ ,  $\text{O}_2$  and also for blood pressure. This centre is under the influence of hypothalamus which is the controller of autonomic activities

(1) **Nervous control :** Brain receives two sets of nerve fibres : Sympathetic and para sympathetic or vagal.

When there is increase in blood  $\text{CO}_2$ , the sympathetic nerve fibres stimulate S.A. node by producing sympathin (adrenaline + noradrenaline). This compound induces impulse generation by inducing entry of  $\text{Ca}^{2+}$  into cardiac muscles. So, heart beat and force of contraction increase (Tachycardia). After action, sympathin is destroyed by sympathenase, COMT (catechol orthomethyl transferase) and MAO (Mono Amino Oxidase)

When there is increase in blood  $\text{O}_2$ , the parasympathetic or vagal (10<sup>th</sup> cranial) nerve inhibits S.A. node by producing acetylcholine. This compound increases contraction time and hence, heart beat is decreased (Bradycardia). After action, acetyl choline is destroyed by enzyme acetyl choline esterase (AChE). This chemical regulation of heart beat on behalf of nerves was discovered by Otto Loewi.

❑ **Vagus escape :** Stimulation of vagus nerve decreases the heart rate but its continuous stimulation shows no further decrease. This phenomenon is called Vagus escape.

(2) **Hormonal control :** Hormones from adrenal medulla adrenaline and nor adrenaline accelerate the heart beat, the latter under normal conditions and the former at the time of emergency. Thyroxine hormone also increases the heart beat by increasing energy production.

❑ **Pounding :** Very fast heart beat during some conditions like anger and love.

#### Factors affecting heart rate

(1) Heart rate increases with increase in basal metabolic rate (BMR)

(2) Heart rate increases as the size of the animals body decreases.

(3) Decrease in pH also increases heart rate.

(4) Heart rate increases with increase in temperature.

(5) Increase in  $\text{Na}^+$  ions in blood or in cardiac muscles, decrease heart rate.

(6) Increase in  $\text{Ca}^{2+}$  ions in blood increases heart beat but if they are injected in cardiac muscles, heart stops in contracted phase which is called Systolic Arrest.

(7) Injection of  $\text{K}^+$  ions in heart muscles stop impulse generation. So, heart stops in diastolic or Relax phase.

(8)  $\text{H}^+$  ions reduces force of contraction of heart.

(9) Increased inspiration, muscular exercise, low oxygen tension, injection of adrenaline, thyroxine, sympathin – all increase heart rate.

(10) Increased expiration, during sleep, Injection of acetylcholine decrease heart rate.

(11) Stenosis – Narrowing of valve is called stenosis.

(12) Alkalosis – Decreases heart rate.

(13) Anoxia – (Absence of  $\text{O}_2$  in tissue) Increases heart rates.

(14)  $\text{CO}_2$  in more amount, decreases heart rate.

(15)  $\text{CO}_2$  in moderate amount, increases heart rate.

(16) Epinephrine and nor-epinephrine increase heart rates.

(17) Thyroid hormone increases heart rate.

#### Cardiac cycle

The sequence of event which takes place from the beginning of one heart beat to the beginning of the next is called as cardiac cycle. Following events are repeated in a cyclic manner during each heart beat.

(1) **Auricular systole** : The atria contract due to wave of contraction stimulated by S.A. node contraction of auricles drives most of their blood into respective ventricles as the A.V. valves are open. There is no backflow of blood into the large veins as the contraction begins at the upper end and passes towards ventricles and moreover, the valves present at the opening of these veins close. Also, blood is already present in large veins which offers resistance to the blood that may return from the atria. At the end of a atrial systole, there starts the relaxation of auricles (auricular diastole) and contraction of ventricles (ventricular systole) simultaneously. Atrial systole takes 0.1 second while atrial diastole is of about 0.7 seconds.

(2) **Ventricular systole** : The ventricles begin to contract due to a wave of contraction stimulated by A.V. node. Due to ventricular systole, the pressure of blood in ventricles immediately rises above that in the auricles. With this pressure, the bicuspid and tricuspid valves close rapidly to prevent the backflow of blood. This closure of A.V. valves at the start of ventricular systole produces first heart sound called "Lubb" or Systolic sound. The semilunar valves are also close at this time. When the pressure of blood in the ventricles exceeds that in the great arteries, the semilunar valves open and blood enters into the great arteries. This marks the end of ventricular systole which takes about 0.3 seconds. Now the ventricles start relaxing (ventricular diastole which lasts for about 0.5 sec.)

(3) **Joint diastole** : The ventricles and auricles are in the diastolic phase simultaneously. As the ventricular diastole progresses, the pressure in the ventricles falls below that in the great arteries. So, to prevent backflow of blood from great arteries into ventricles, the semilunar valves close rapidly. This rapid closure of semilunar valves at the beginning of ventricular diastole produces second heart sound "Dup" or diastolic sound.

#### Heart Sounds

Heart sounds can be listened with the help of an instrument called STETHOSCOPE. It was invented by Laennec.

There are four heart sounds, designated as  $S_1$ ,  $S_2$ ,  $S_3$  and  $S_4$ .

**First Heart Sound** :  $S_1$  is known as "LUBB" a long and louder sound produced by the closure of atrioventricular valves (tricuspid and bicuspid) at the beginning of ventricular system.

**Second Heart Sound** :  $S_2$  is known as "DUP" a short and sharper sound created by the closure of semilunar valves towards the end of ventricular systole.

**Third And Fourth Heart Sounds** :  $S_3$  and  $S_4$  are usually very faint sounds and hence may not be audible. These sounds are associated with rapid ventricular filling ( $S_3$ ) and atrial systole ( $S_4$ )

Heart sounds provides valuable information about working of valves. Defective or damaged heart valves lead to the backflow of blood either from ventricles to auricles or from aorta to ventricles. Such defects are detectable as abnormal hissing sound called 'MURMER'. Defective valves may be replaced or repaired surgically.

The instrument used to magnify and record the heart sound is called PHONOCARDIOGRAM.

During joint diastole, blood from great veins and coronary sinus flows into the atria and some blood also passes from auricles into the respective relaxing ventricles due to less pressure in ventricles. This phase takes only 0.4 seconds and is also called as blood receiving period of heart. Thus a cardiac cycle is completed in 0.8 seconds.

**Cardiac output** : Volume of blood pumped from heart (left ventricle) into the systemic aorta in one minute is called cardiac output. It is also called minute volume. It is calculated as the product of stroke volume (amount of blood pumped by left ventricle each time it contracts) and rate of heart beat.

i.e. Cardiac output = Stroke volume  $\times$  Rate of heart beat

= 70 ml  $\times$  75 times/minute = 5250 ml/minute or 5.25 litres/min

Total amount of blood in human body is about 5 litres (7% of body weight). During mild exercise, the cardiac output rises to about 11 litres. During intense exercise, cardiac output rises to 19.5 litres/min., and heart beat may rise to 130 beat/minute. Cardiac output is directly proportional to the size of the organism, metabolic rate etc. but is inversely proportional to age.

(1) **Fractions of cardiac output** : Amount of pure blood going to an organ per minute is called as fraction of the organ.

(i) Cardiac fraction – 200 ml/min.

(ii) Hepatic fraction (maximum) – 1500 ml/min. (28% of blood as liver is the busiest organ of body and has maximum power of regeneration).

(iii) Renal fraction – 1300 ml/min (25% of blood)

(iv) Myofraction – 600-900 ml/min.

(v) Cephalic organs (brain) – 700-800 ml/min.

(vi) Remaining organs – Remaining blood.

(2) **Cardiac index** : Cardiac output per square metre of body surface area per minute. As area of normal young adult is 1.7 metre square, so, cardiac index is 3 litres/min/square metre.

(3) **Cardiac reserve** : Maximum amount of blood that can be pumped by left ventricle under the conditions of maximum needs. In this condition, heart beat can go upto 250 and stroke volume can go upto 100 ml per systole. Cardiac reserve is 25-30 litres which is about 5-6 times of cardiac output.

(4) **End diastolic volume (EDV)** : Amount of blood present in left ventricle at the end of diastole. It is the maximum volume of the cavity of left ventricle and is equal to 120-130 ml.

(5) **End systolic volume (ESV)** : Amount of blood present in left ventricle at the end of systole. It is the least volume of the cavity of left ventricle and is equal to 50-60 ml.

(6) **Stroke volume** : (70 ml) is equal to the difference between the end diastolic volume and end systolic volume.

$$SV = EDV - ESV$$

(7) **Venous return** : Amount of impure blood returning to right atrium per minute is called venous return and is equal to 5.25 litres.

#### Electrocardiogram (ECG)

A graphic record of electrical events occurring during a cardiac cycle is called Electrocardiogram. It was invented by Einthoven. The instrument used for recording the heart's electrical variations is called Electrocardiograph in which the potential differences of heart muscles are recorded by a galvanometer. In ECG, there are 2 types of waves :

(1) **Depolarisation waves** : They represent the generation of the potential difference. These waves appear only when both electrodes of galvanometer are in different fields. When both the electrodes are in same field, there is no deflection and wave drops down to base line

(2) **Repolarisation waves** : They appear when depolarisation is over and the muscle fibre is returning to its original polarity. When both electrodes are in same polarity (means 100% repolarisation and 100% depolarisation), there is no deflection.

A normal ECG has 5 deflection waves – P, Q, R, S and T. Out of them – P, R and T waves are above the base line and are called positive waves. The Q and S waves are below base line and are called negative waves. The part of the base line between any 2 deflections is called Interval.

**P wave** : Indicates impulse of contraction generated by S.A. node and its spread in atria causing atrial depolarisation. The interval PQ represents atrial contraction and takes 0.1 second.

**QRS complex** : Indicates spread of impulse of contraction from A.V node to the wall of ventricles through bundle of His and Purkinje fibres causing ventricular depolarisation. This complex also represents repolarization of S.A. node.

The RS of QRS wave and ST interval show ventricular contraction (0.3 seconds). QRS is related to ventricular systole.

**T wave** : Indicates repolarisation during ventricular relaxation.

Any abnormality in the working of heart alters the wave pattern of ECG. Thus, ECG is of great diagnostic value in cardiac diseases. ECG also indicates the rate of heart beat

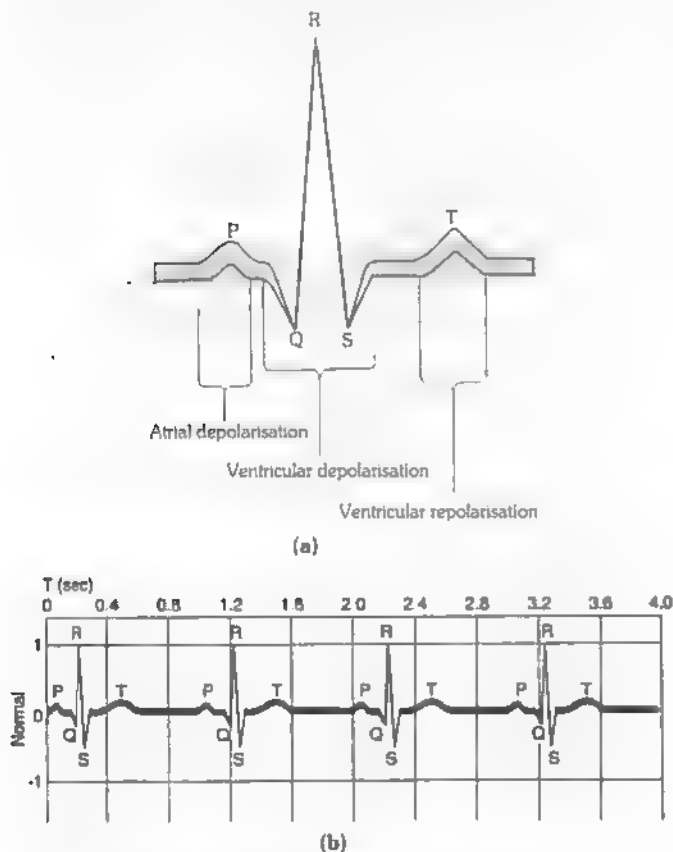


Fig : 5.3-9 (a) Normal ECG deflections, Depolarisation and repolarisation (b) Normal electrocardiogram

## Blood vessels

The study of blood vessels is called Angiology. The blood vessels are of following types :

(1) **Arteries** : Thick walled, carrying oxygenated blood (deoxygenated in pulmonary artery) from heart to various parts of body. These blood vessels are grouped as Aorta which branches to form arteries which further divides into thinner branches called arterioles inside the organ. Average diameter of arteriole is  $120 \mu\text{m}$ . The arterioles further divide into smaller vessels called meta-arterioles ( $70 \mu\text{m}$ ) which divide into capillaries. At the beginning of capillary, the arterioles possess circular muscles called precapillary sphincter which regulates flow of blood into the capillaries which is called vasomotion. Smooth muscles of arteries are innervated by sympathetic fibers, their stimulation control vasoconstriction and vasodilation. Smooth muscles of arteries and arterioles also limit bleeding from wounds by producing vascular spasm during cut. Arteries are of two types.

- (i) Conducting or elastic arteries
- (ii) Distributing or muscular arteries.

Elastic or conducting arteries receive blood from heart and do not provide it to any organ rather they provide blood to other arteries and are pressure reservoirs of blood.

Muscleless end of meta-arteriole is called thoroughfare channel or preferential channel.

The largest artery is dorsal / abdominal aorta (systemic aorta).

**Anastomosis** : If more than one arteries are supplying to one organ then branches of these arteries unite to form a network called Anastomosis. It provides many collateral or alternate pathways of blood supply. So, if there is blocking of any artery, it will not lead to necrosis.

(2) **Capillaries** : Smallest blood vessels, discovered by Marcello Malpighi. The wall is formed of single layer of endothelium resting on a basement membrane. Diameter of capillary is about  $8 \mu\text{m}$ . These are also called as exchange vessels as they are the site of exchange of material between blood and tissue because of least barrier in them. The capillaries can be grouped into two categories :

- (i) **Arteriolar capillary** : Which supplies nutrition, respiratory gases etc. to the body cells.
- (ii) **Venular capillaries** : Which collect the metabolic wastes from the body cells.

Capillaries possess about 7% of total body blood and are present near almost all cells of body in the intercellular spaces. The tissues which are devoid of intercellular spaces are also devoid of capillary. They are called avascular tissues.

Capillaries are surrounded by cells of connective tissue called pericapillary cells. Some of these cells are contractile and phagocytic in nature and are called Rouget cells or pericytes.

Continuous capillaries are without fenestra/aperture, hence are less permeable. These are present in organs such as lungs, muscles, connective tissues and brain tissues.



Fenestrated capillaries possess apertures/fenestra and are found in those organs where there is maximum need of permeability such as endocrine glands, intestinal villi, cavities of brain, kidney, ciliary body of eye.

Sinusoids are irregularly dilated capillaries found in organs where there is decrease in flow rate such as liver, spleen, bone marrow, parathyroid, pituitary gland. In liver, sinusoids are branches of venules and open into venules while in other organs, they originate from arteriole and unite to form venules.

(3) **Veins** : These are thin walled, carrying deoxygenated blood (oxygenated in pulmonary vein) from tissues to the heart. Venules, smallest branches, unite to form veins which in turn unite to form vena cava. The largest vein is inferior vena cava/post caval. Varicose veins are stout, blood filled painful veins specially of the limbs due to defective watch pocket valves.

#### Histology of arteries and veins

(1) **Tunica externa or tunica adventitia** : Outermost, fibrous, made up of collagen rich connective tissue and less elastin fibres. The collagen fibres give strength to the blood vessels and prevent their over dilation.

(2) **Tunica media** : Middle, thickest, made up of smooth involuntary muscle fibres and elastin fibres. This layer is very much variable because number of elastin fibres and muscle fibres depend upon the position of blood vessels from the heart.

(3) **Tunica interna or tunica intima** : Innermost, thinnest, made up of inner, single layer of simple squamous epithelial cells called endothelium resting on a basement membrane and outer layer of elastic (yellow fibrous) connective tissue. The hollow space in the blood vessel is called lumen.

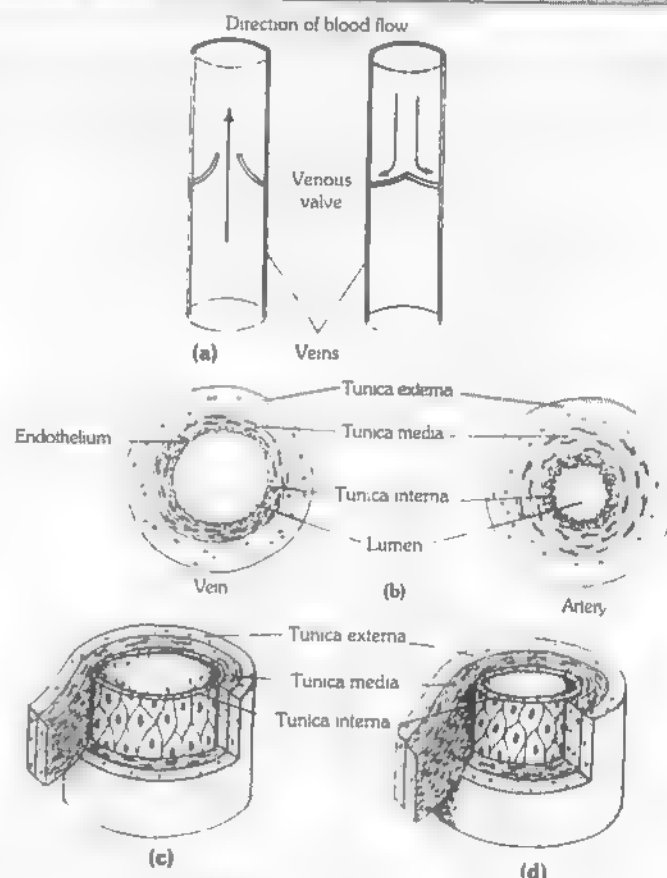


Fig : 5.3-10 (a) Venous valves, (b-d) Histology of the blood vessels

Table : 5.3-5 Differences between arteries and veins

S No.	Characters	Arteries	Veins
(1)	Wall	Thick, more elastic, non collapsible	Thin, less elastic, collapsible
(2)	Tunica externa	Less developed, so less strong	More developed, so more strong.
(3)	Tunica media	More muscular and has many elastic fibres	Less muscular and only a few elastic fibres
(4)	Tunica interna	Endothelial cells more elongated Elastic membrane more developed.	Endothelial cells less flat Elastic membrane less developed.
(5)	Lumen	Narrow	Wider
(6)	Position	Deep seated except wrist, neck etc	Superficial
(7)	Valves	Without valves	With valves to prevent back flow
(8)	Direction of blood flow	From heart to body organs	From body organs to heart
(9)	Nature of blood	Oxygenated except pulmonary artery	Deoxygenated except pulmonary vein
(10)	Blood pressure	More, generally 120/80 mm of Hg	Less, generally 0 mm of Hg
(11)	Speed of blood	Fast	Slow
(12)	After death	Becomes empty	Contain blood
(13)	Amount of blood	15% at any given time.	64% at any given time
(14)	Colour	Pink	Dark red
(15)	Distensibility	Less	More
(16)	Average Blood pressure	More	Less
(17)	Elastic-lamina	Present	Absent

**Blood pressure** : The lateral pressure exerted by the column of blood on the wall of the blood vessels in which it is present is called blood pressure. It is usually measured in brachial artery by an instrument called sphygmomanometer (invented by Riva-Rocci 1896). Arterial blood pressure is of 2 types :

(1) **Systolic blood pressure** : It is the pressure exerted by blood on the walls of the blood vessels due to the systole of ventricles and is equal to 120 mm Hg during ventricular systole, there is expansion in the artery due to the uncoiling of elastic layer. Hence, the pressure is maximum in arteries but gradually decreases in capillaries and veins.

(2) **Diastolic blood pressure** : It is the pressure exerted on walls of blood vessels when the ventricles are relaxed. During ventricular diastole, the uncoiled elastic layer recoils leading to normalization of artery. Hence, blood pressure drops down to 80 mm Hg. Thus, blood pressure in normal person is systolic/diastolic pressure i.e. 120/80 mm Hg.

(3) **Pulse pressure** : The difference between systolic and diastolic pressures is called pulse pressure and its normal value is  $120 - 80 \text{ mm Hg} = 40 \text{ mm Hg}$ . It provides information about the condition of arteries.

(4) **Mean arterial pressure** : It is the average pressure of systolic and diastolic pressures. As the blood remains in the systolic phase for shorter period and in the diastolic phase for longer period, the mean pressure of blood lies near the diastolic pressure.

This value varies at different levels of circulation being maximum (100 mm Hg) in the aorta and minimum (0 mm Hg) in the venae cavae under normal conditions.

**Pulse** : It is the pressure wave of distension and recoiling felt in the radial artery due to the contraction of left ventricle which force about 70-90 ml of blood in each cardiac cycle to aorta. This pressure wave of contraction travels down to the wall of the arteries and is called the pulse.

The pulse is measured in the radial artery in the wrist but can be felt in the temporal artery over the temporal bone or the dorsal pedis artery at the back of ankle. The pulse normally travels at the rate of 5-8 m/second.

Since each heart beat generates one pulse in the arteries so the pulse rate per minute indicates the rate of heart beat. So the normal pulse rate in a normal adult person is 72/minute.

The normal ratio of systolic pressure to diastolic pressure to pulse pressure is about 3 : 2 : 1

#### Factors affecting blood pressure

(1) **Age** : With the advancing age, BP increases after the age of 60 years, it is calculated as  $100 + \text{age of the person}$ .

(2) **Cardiac output** : BP increases with the increase in cardiac output

(3) **Elasticity of blood vessels** : BP is inversely related to the elasticity of the blood vessels.

(4) **Total peripheral resistance** : Constriction of the blood vessels increases BP whereas dilatation of the blood vessels decreases BP

**Hypotension** : Low blood pressure with systolic below 110 mm Hg and diastolic below 70 mm Hg. It is caused by low metabolic rate, starvation, anaemia, chronic vasodilation of arterioles, lower pumping activity of heart, loss of blood in haemorrhage, valvular defects, nervous disorders and Addison's disease. It may cause fainting. Also due to lowering of oxytocin, Acetylcholine, ANP (Atrial Natriuretic Peptide) Low  $\text{Ca}^{++}$ , Low BMR.

**Hypertension** : Persistent high blood pressure with systolic more than 140 mm Hg and diastolic more than 90 mm Hg. It is caused by decrease in extensibility of the artery due to atherosclerosis and arteriosclerosis. Sclerosis means hardening and narrowing of blood vessels which may be due to the deposition of cholesterol or calcium or lipid or any other compound in the wall of the arteries and arterioles.

In atherosclerosis deposition is mainly in tunica intima of the blood vessels which prevents their dilation. The atherosclerosis is, in fact, the beginning of thickening and hardening of blood vessels but later, the deposition of cholesterol and other compounds takes place in both tunica media and tunica intima leading to arteriosclerosis.

Hypertension caused by hormones (epinephrine, aldosterone, renin) is called secondary hypertension, other forms of hypertension are known as primary or essential hypertension.

### Blood circulation in human

The physiology of blood circulation was first described by Sir William Harvey in 1628. The blood circulation in our body is divisible into 3 circuits –

(1) **Coronary circulation** : It involves blood supply to the heart wall and also drainage of the heart wall.

(i) **Coronary arteries** : One pair, arising from the aortic arch just above the semilunar valves. They break up into capillaries to supply oxygenated blood to the heart wall.

(ii) **Coronary veins** : Numerous, collecting deoxygenated blood from the heart wall and drains it into right auricle through coronary sinus which is formed by joining of most of the coronary veins. But some very fine coronary veins, called venae cordis minimae open directly in the right auricle by small sized openings called foramina of Thebesius.

(2) **Pulmonary circulation** : It includes circulation between heart and lungs. The right ventricle pumps deoxygenated blood into a single, thick vessel called pulmonary aorta which ascends upward and outside heart gets divided into longer, right and shorter, left pulmonary arteries running to the respective lungs where oxygenation of blood takes place. The oxygenated blood from lungs is returned to the left auricle by four pulmonary veins. Left auricle pumps this blood into the left ventricle.

(3) **Systemic circulation** : In this, circulation of blood occurs between heart and body organs. The left ventricle pumps the oxygenated blood into systemic arch which supplies it to the body organs other than lungs through a number of arteries. The deoxygenated blood from these organs is returned to the right auricle through two large veins (precaval and post caval). Right auricle pumps this blood into the right ventricle. Thus, the systemic circulation involves two circuits –

**Arterial system**

It involves aorta, arteries, arterioles and meta-arterioles. It supplies oxygenated blood to all parts of the body except lungs.

The left ventricle of the heart pumps the oxygenated blood into a single, question marked shaped, long vessel called left carotid-systemic aorta. It is the largest blood vessel of the body.

After ascending from the heart, the systemic aorta turns and descends down to the level of lower border of fourth lumbar vertebra. At its distal extremity, it bifurcates into right and left common iliac arteries. The systemic aorta has following parts –

(1) **Ascending aorta** : It gives off left and right coronary arteries

**Brachiocephalic (innominate)** : Unpaired, largest branch of the aorta divides into right subclavian towards right side and right common carotid towards left side. Right subclavian gives off vertebral artery (supplies to head and part of right shoulder) and then enters into right arm, now called axillary artery or brachial artery, which divides into ulnar and radial arteries in the region of elbow. The right common carotid, enters into head and divides into external and internal carotids which supply the right parts of head by their branches.

**Left common carotid** : Unpaired artery, enters into head and divides into left external and internal carotids which supply the left part of the head by their tributaries. The external carotids of both sides provide blood to thyroid gland, tongue, throat, face, ear, scalp. The internal carotids of both sides supply to brain, eye, inner part of nose and forehead. These internal carotids go upward and enter skull through foramen magnum and unite at the base of brain along with the vertebral arteries of both sides. So, there is formation of a ring shaped artery called as "Circle of willis". From this circle, many branches or arteries arise which go to different parts of brain.

In frog, the internal carotid has at its base, carotid labyrinth (spongy mass of non-contractile fibro-elastic tissue) which acts as a sensory organ to detect blood pressure in artery

**Left subclavian artery** : Unpaired artery, it gives off a left vertebral artery (supplies to head and part of left shoulder) and then enters into left arm, now called left axillary artery or left brachial artery which divides into ulnar and radial arteries in the region of elbow.

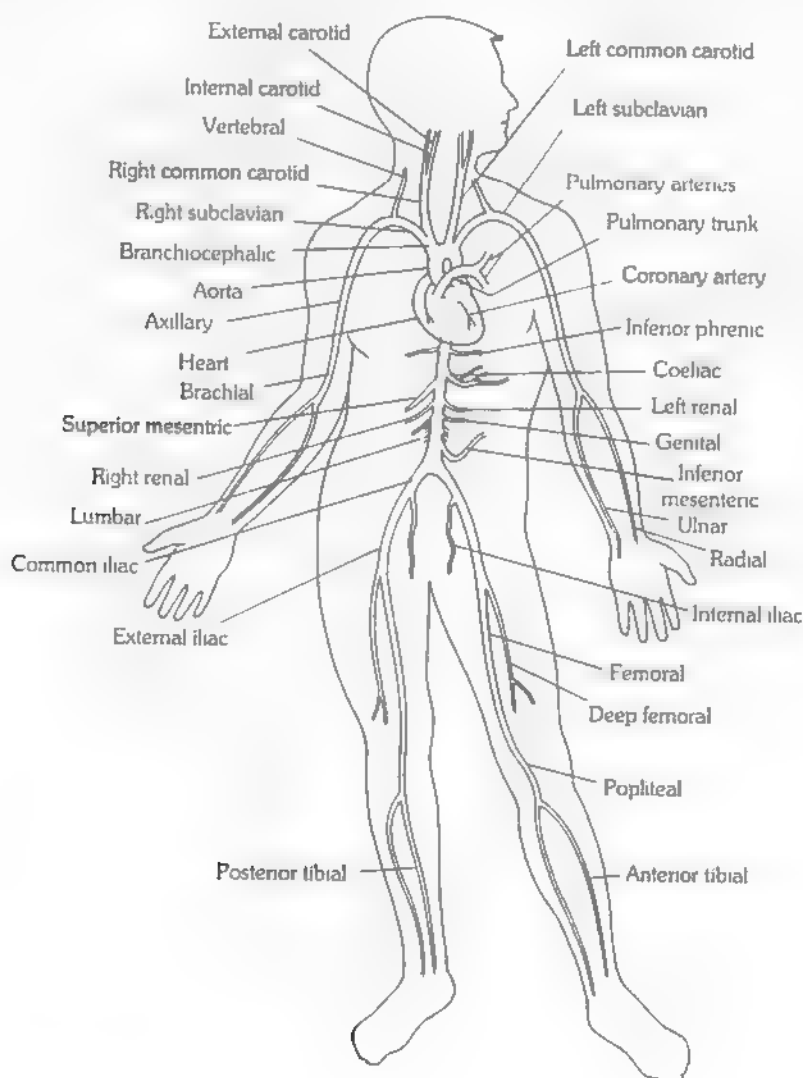


Fig : 5.3-11 Arterial system in human body

(2) **Descending aorta** : The aorta turns towards the back of heart and finally converts into dorsal aorta. The descending dorsal aorta is called thoracic aorta in thoracic region and abdominal aorta in abdominal region.

**From thoracic segment of aorta** : Several pairs of small arteries arise in this region to supply various parts such as pericardium (pericardial artery); lungs and bronchi (bronchial artery); oesophagus (oesophageal artery); mediastinal organs and thymus (mediastinal artery); intercostal muscles and mammary glands (intercostals and subcostal arteries); upper surface of diaphragm (superior phrenic artery).

**From abdominal region of aorta** : In the abdominal region, abdominal aorta gives off several pairs of arteries. Some of the major ones are as follows –

**Inferior phrenic artery** : Right and left to supply the lower surface of the diaphragm.

**Coeliac artery** : Unpaired, divides into three branches

(i) **Left gastric artery** : To stomach.

(ii) **Common hepatic artery** : To pylorus, pancreas, gall bladder, liver, cystic duct, hepatic ducts etc.

(iii) **Splenic artery** : To pancreas, stomach and spleen.

**Superior mesenteric** : Unpaired, supplies various parts of small intestine (except superior part of duodenum part of colon and caecum). Its sub branches are

(i) **Pancreo duodenal artery** : To pancreas and duodenum.

(ii) **Jejunal artery** : To jejunum.

(iii) **Iliac artery** : To ileum and jejunum.

(iv) **Iliocolic artery** : To ileum and colon.

**Supra renal artery** : Supplies the adrenal glands.

**Renal arteries** : One pair, supply to kidney.

**Lumbar arteries** : 4 pairs, supply the skin, muscles, joints, vertebrae, meninges, spinal cord etc. in the lumbar region.

**Sacral artery** : Supplies the tissues of sacral region.

**Inferior mesenteric artery** : Unpaired, supplies most part of colon, rectum and anal canal.

**Common iliac arteries** : Two, right and left, formed by bifurcation of aorta at its lower end. Each common iliac artery divides into external and internal iliac arteries. The internal iliac (hypogastric) artery supplies viscera and wall of pelvic region, perineum and gluteal regions. The external iliac artery enters into the leg now called femoral artery continues down the thigh, now called popliteal artery which bifurcates into anterior and posterior tibial arteries, at about the level of knee.

### **Venous system**

It originates in tissues by union of capillaries and ends in the atrium of heart. It includes two major veins – superior and inferior vena cava which drain the deoxygenated blood into the right atrium.

(1) **Superior vena cava (pre caval)** : Single, formed by the union of right and left brachiocephalic (innominate) veins. It collects blood from head, neck, arms and chest region. It involves the following veins –

**Brachiocephalic veins** : Two, each is formed by the union of an outer subclavian vein and medial internal jugular vein. Each vein also receives blood from different thoracic parts of its sides through three main veins.

(i) **Internal thoracic vein** : From some muscles and mammary glands.

(ii) **Inferior thyroid vein** : From thyroid gland.

(iii) **Left superior intercostal vein** : From upper part of thorax.

**Internal jugular vein** : Two, right and left. Each one is formed by the union of numerous sinuses and veins of the cranial cavity, superior part of the face and some part of neck and collects blood from these regions.

**Subclavian veins** : Two, right and left, formed in the shoulder region by union of cephalic and axillary veins of respective sides.

(i) **Axillary veins** : Two, right and left, present in the respective arms and collect blood from these regions.

(ii) **Cephalic veins** : Two, right and left, collect blood from respective arms and shoulder region.

**External jugular veins** : Two, right and left, open into respective subclavian vein. They collect the blood from parotid gland, facial muscles and superficial parts of cranium.

**Azygos and hemiazygos veins** : Azygos vein originates in lumbar region towards right side of mediastinum and ascends upwards small veins from lumbar and thoracic parts of backbone, oesophagus, mediastinum, pericardium etc. empty into it.

Towards the left side of the body originates hemiazygos and accessory hemiazygos collects blood from oesophagus, mediastinum, intercostal muscles, mammary glands etc. and drains into Azygos which in turn opens into superior vena cava. Accessory hemiazygos drains blood into left innominate vein.

(2) **Inferior vena cava (Post caval)** : It is the largest vein, originated in inferior lumbar region by the union of right and left common iliac veins and opens into right atrium by separate opening. It collects blood from all body structures below the diaphragm. It involves following veins –

**Common iliac veins** : Two, right and left. Each one is formed by union of external and internal iliac veins.

**External iliac vein** : This is the continuation of femoral vein which collects blood from leg. Femoral vein in turn is formed by the union of anterior tibial vein, posterior tibial vein, popliteal vein, large saphenous vein, small saphenous vein, etc. which collect blood from different parts of leg. External iliac vein also collects blood from pubic region and parts of pelvis through number of small veins. Great saphenous vein is the longest vein of the body.

**Internal iliac (Hypogastric) veins** : Two, right and left. Each one is formed by union of number of small veins, which collect blood from pelvis, pelvic viscera, pelvic girdle, sacrum, rectum, ureter, urinary bladder, uterus, vagina, prostate glands, seminal vesicle, penis, scrotum etc. (i.e. number of reproductive organs).

**Lumbar veins :** Four pairs, which collect blood from muscles, skin and vertebrae of lumbar region and drains it into inferior vena cava.

**Genital veins :** In man, right testicular vein collects blood from male organs and inguinal regions and drains it into inferior vena cava. Left testicular vein drains the blood into left renal vein. In woman, the right ovarian vein drain blood from ovaries, uterus etc. and empties into inferior vena cava. The left ovarian vein opens into left renal vein.

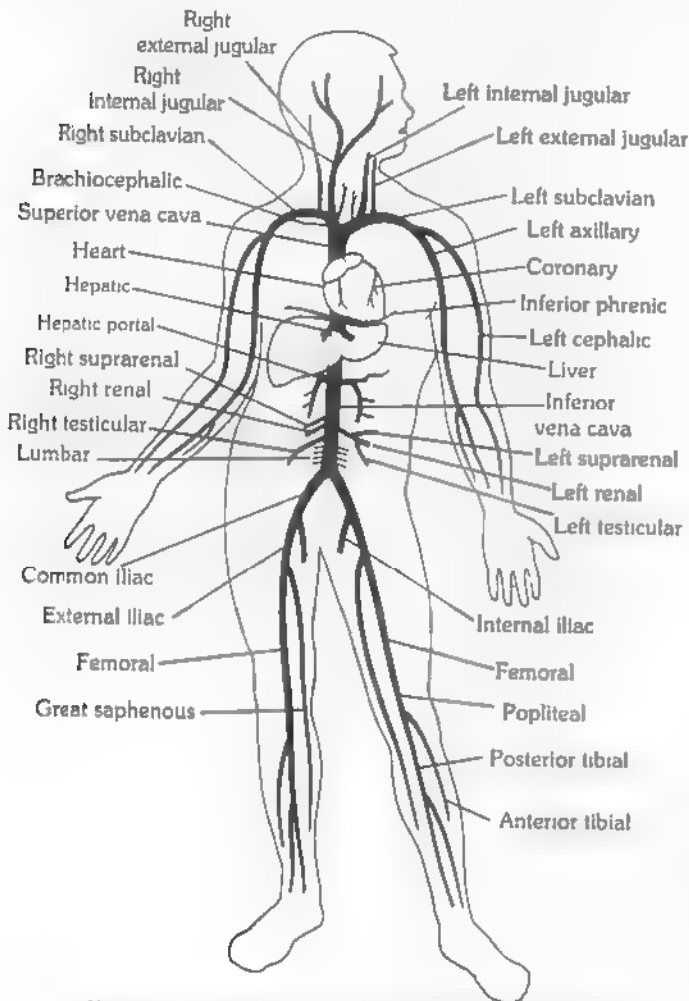


Fig : 5.3-12 Venous system in male human being

**Renal veins :** Two, right and left collect blood from respective kidneys and open into inferior vena cava. The left renal vein is about three times longer than the right one.

**Suprarenal vein :** Two, right and left, collect blood from adrenal glands. Right one opens into inferior vena cava whereas left one opens into left renal vein.

**Inferior phrenic veins :** These veins drain the blood from lower surface of diaphragm. The right one ends in post caval. The left one is often doubled with its one branch ending in left renal or suprarenal vein and the other in post caval.

**Hepatic veins :** They drain blood from liver into the post caval. Urea is maximum in hepatic vein while it is minimum in renal vein.

## Portal system

It is a part of venous circulation which is present between two groups of capillaries i.e. starts in capillaries and ends in capillaries. The vein which drains blood into organs other than heart is called portal vein.

**Types of portal system :** It is of following types :

(1) **Hypothalamo-hypophyseal portal system :** Present in higher vertebrates (amphibia, reptiles, birds and mammals). Blood from hypothalamus is collected by hypophyseal portal vein which ends in anterior lobe of pituitary gland. The superior hypophyseal artery which brings blood into circle of willis bifurcates outside the lobe; one branch supplies the lobe itself, but the other one supplies the hypothalamus. The vein that drains the blood from hypothalamus then runs into pars distalis and divides into capillaries. Thus this is a portal vein called hypothalamo-hypophyseal portal vein.

**Function :** This portal system enables the releasing factors and inhibiting factors from hypothalamus to reach up to anterior pituitary.

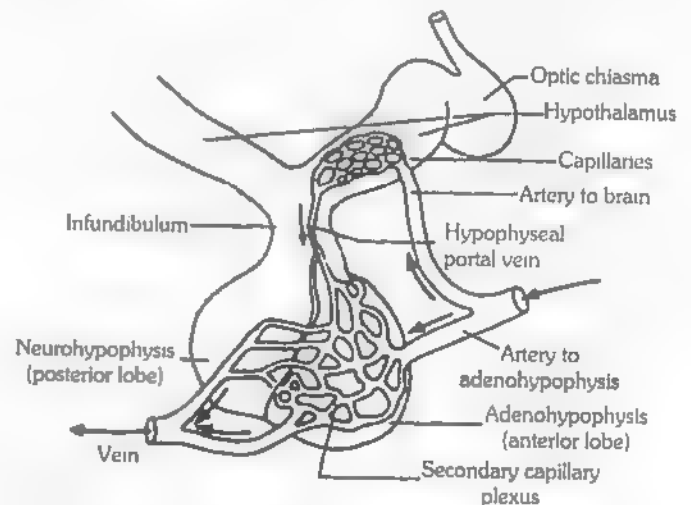


Fig : 5.3-13 Human hypothalamo-hypophyseal portal system

(2) **Hepatic portal system :** Found in all chordates. In mammals, there is a single vein called hepatic portal vein, formed by the union of six main veins, which drain venous blood from different parts of alimentary canal (digestive system) into the liver. These veins are :

(i) **Posterior or Inferior mesenteric vein :** Collect blood from rectal wall and anal region. This vein possesses maximum diluted blood. Posterior mesenteric is made up of joining of 4 small veins that are rectal vein, sigmoid vein, left colonic vein and it opens into the splenic vein.

(ii) **Anterior or Superior mesenteric vein :** Collect blood from wall of colon, caecum and small intestine. This vein possesses largest concentration of nutrients (glucose, amino-acid and vitamins). This vein is formed by the joining of right colonic vein, ileocolic vein and appendicular vein.

(iii) **Splenic vein** : Collect blood from spleen and pancreas, splenic vein possess free haemoglobin in large amount.

(iv) **Right gastric vein** : Receives blood from stomach.

(v) **Left gastric vein** : Receives blood from stomach and pancreas.

(vi) **Cystic vein** : Receives blood from gall bladder.

Posterior mesenteric vein open into splenic vein and splenic, anterior mesenteric, right gastric fused to form hepatic portal vein, which leads blood into the liver.

In amphibians (example – frog), hepatic portal system is formed of single hepatic portal vein and single anterior abdominal vein. The latter collects blood from leg region and drains it into the left lobe of liver.

**Significance of hepatic portal system** : The hepatic portal system has following significance.

(a) The blood which comes from the alimentary canal contains digested food like glucose and amino acids. The excess of glucose is converted into glycogen which is stored in the liver for later use. When an individual feels deficiency of food, the glycogen is converted into glucose and is transferred to the blood stream via hepatic veins.

(b) Harmful nitrogenous waste like ammonia is converted into urea which is later removed by kidneys. Thus the blood is detoxified (purified) of harmful nitrogenous waste

(c) Liver produces blood proteins which are put into blood circulation.

(3) **Renal portal system** : It is well developed in fishes and amphibians, it is reduced in reptiles and birds and is absent in mammals. This system carries blood from the posterior region of the body to the kidneys by renal portal veins, hence its name. The kidneys remove the waste products from the blood and then the blood is passed to the post caval by renal veins. Why renal portal system is absent in mammals ? The mammals have no renal portal system because, the heart of mammals is four chambered. Due to the four chambered heart in mammals there is total separation of oxygenated and deoxygenated blood.

Renal portal system in frog consists of one pair of renal portal vein, each one formed by the union of femoral vein and sciatic vein. It collects blood from leg region and drains it into kidney. It also collects blood from dorsal part of lumbar region through dorsolumbar vein.

**Function** : Renal portal system helps in blood filtration by draining it into kidney which filters the blood

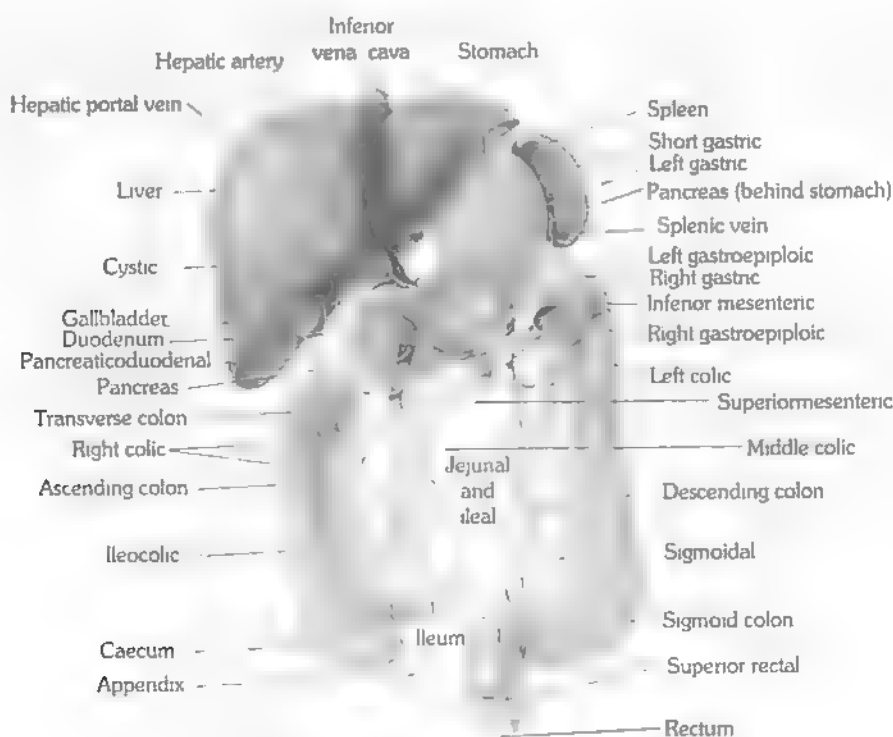


Fig : 5.3-14 Human hepatic portal system

## Lymphatic system

It is a part of greater circulation which begins in the tissue fluid with lymphatic capillaries which are always terminally closed. This system terminates into venous system near heart. The main components of this system are :

(1) **Lymph** : Lymph can be defined as blood minus RBC's. In addition to the blood vascular system all vertebrate possess a lymphatic system. It is colourless or yellowish fluid present in the lymph vessels. It is a mobile connective tissue like blood and is formed by the filtration of blood. This process involves the diffusion of substances from blood capillaries into the interstitial space which is, thus, the primary site of lymph formation. Two forces bring about a steady filtration of plasma fluid into the tissue spaces : capillary pressure (30-35 mm Hg) and colloid osmotic pressure in tissue fluid (8 mm Hg). After absorption by veins, a small amount of  $\text{CO}_2$  and waste material still remains in the tissue fluid which is absorbed in the lymphatic capillaries as lymph. So, we can say that lymph is modified tissue fluid.

Table : 5.3-6 Differences between lymph and blood

S.No.	Characters	Blood	Lymph
(1)	RBC	Present	Absent
(2)	Blood platelets	Present	Absent
(3)	WBC	Present, generally 7000/cu mm	Present, generally 500-75000/cu mm
(4)	Plasma	Present	Present
(5)	Albumin . globulin	Albumin > Globulin	Albumin > Globulin
(6)	Fibrinogen	More	Less
(7)	Coagulation property	More	Less
(8)	Direction of flow	Two way, heart to tissues and tissues to heart	One way, tissues to heart
(9)	Rate of flow	Fast	Slow
(10)	Glucose, urea and $\text{CO}_2$	Less	More

Hence, lymph can be represented as :

Lymph = Blood - [RBC + platelets + plasma proteins of high molecular weight]

**Composition of lymph** : Microscopic examination of lymph depicts that it contains a large number of leucocytes (mostly lymphocytes) ranging from 500 to 75,000 per cubic mm. No blood platelets present. The composition of the non cellular part of lymph (fasting) is as follows :

(i) Water 94%                      (ii) Solids 6%

(a) **Proteins** : Protein content is roughly half of the plasma and varies from 2.0 - 4.5%. It varies according to the part of the body from which it is collected, i.e. in liver 6%, in limb 2%, in intestinal part 4%. The varieties of proteins are found - albumin, globulin and fibrinogen. In addition to this, traces of prothrombin, fibrinogen are also found.

(b) **Fats** : In fasting condition fat content is low but after a fatty diet it may be 5.0 - 15%.

(c) **Carbohydrates** : Sugar, 132.2 mg per 100 ml.

(d) **Other constituents** : Urea, creatinine, chlorides, phosphorus, calcium, enzymes and antibodies (120 ml./hour).

□ Normally the rate of lymph formation is equal to the rate of its return to the blood stream. But occasionally the rate of lymph formation exceeds its return to the blood stream which causes accumulation of fluid around the cells resulting in dropsy or oedema.

(2) **Lymphatic organs** : In human primary lymphatic (lymphoid) organs of the body are the Red bone marrow and Thymus gland. They are called primary lymphatic organs because they produce B and T cells the lymphocytes that carry out immune response. Haemopoietic stem cells in red bone marrow gives rise to B Cell and pre-T cells. Pre-T cells then migrate to thymus gland. Secondary lymphatic organs are the lymph nodes and spleen.

(i) **Spleen** : Spleen is mesodermal in origin. Spleen is the largest solid mass of reticulo-endothelial tissue in the body. In human it measures about 12 cm (5 inch) in length and is situated in the left hypochondriac regions between the stomach and diaphragm. Like lymph nodes, spleen has hilus, where splenic artery, vein and efferent lymphatic vessels pass through. Spleen never filter lymph, because it has no afferent lymphatic vessel. Histologically it is formed by following structure -

(a) **Capsule** : It is the outer covering of spleen formed of dense connective tissue and smooth muscles. The outer layer of the capsule is the serous coat formed of visceral peritoneum.

(b) **Trabeculae** : Narrow fold like septa or trabeculae extend inwards from the capsule, dividing the spleen tissue into several incomplete lobules. They provide support and convey blood vessels into the interior of spleen.

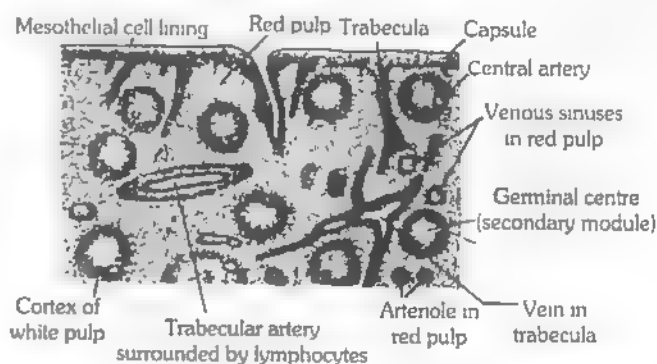
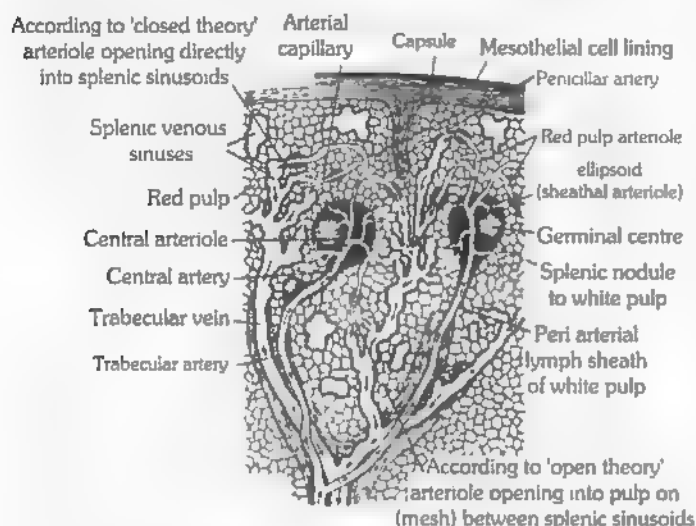


Fig : 5.3-15 Histological structure of spleen (Diagrammatic)

(c) **Splenic pulp** : The reticulo-endothelial tissue is called splenic pulp. It contains a denser network of blood capillaries, small sinuses and fine blood vessels. The meshes of this network are studded with numerous splenic cells, red, blood corpuscles, macrophages and lymphocytes. The splenic pulp is of two distinct types -

(i) White pulp                      (ii) Red pulp

In mammal embryos the red pulp contains myelocytes, erythroblast and also megakaryocytes. These types of cells are not present in adult spleen except in certain pathological condition.



**Fig : 5.3-16 Anatomy of circulation in a splenic lobule showing both closed circulation and open circulation (Diagrammatic)**

**Function :** Although located close to the alimentary canal, the spleen has nothing to do with digestive system. It is, in fact, an important constituent of the reticuloendothelial system of body and performs the following functions:

(a) Its macrophages engulf (= phagocytize) and destroy worn out blood corpuscles (RBC + platelets), dead and live pathogens, cell debris, pigment granules and other useless particulate materials, thus regularly cleaning the blood of its impurities.

(b) It is active haemopoietic organ. In foetal life, the red pulp possess myeloblast, erythroblast and megakaryocytes. Hence, in foetus, it produces blood. In adults, the red pulp possess macrophages, plasma cells and lymphocytes. So, in adults, it is not producing blood rather it is screening blood.

(c) In adults, it also serves as a sort of "blood bank". Its sinuses act as "reservoirs of blood".

(d) White pulp of spleen functions in immunity as a site of B cell proliferation into antibody-producing plasma cells.

(e) Spleen also acts as Graveyard or Slaughter house of worn out RBCs.

(f) Haemolysin is formed in spleen (Lysolecithin).

(g) Haemoglobin is broken down into haem and globin by spleen.

Besides all these functions, the primary function of spleen is that it assists liver and helps in maintaining the composition of blood.

(ii) **Thymus gland :** In human thymus is located in mediastinum, between the lungs. The two thymic lobes divide into lobules by trabeculae. Each lobule consist of cortex and medulla. Cortex composed of tightly packed lymphocytes, epithelial cells, Macrophages. Pre-T cells migrates (via blood) from red bone marrow to thymus, where they proliferates and develop into mature T cells. Medulla consist of mostly of epithelial cells and

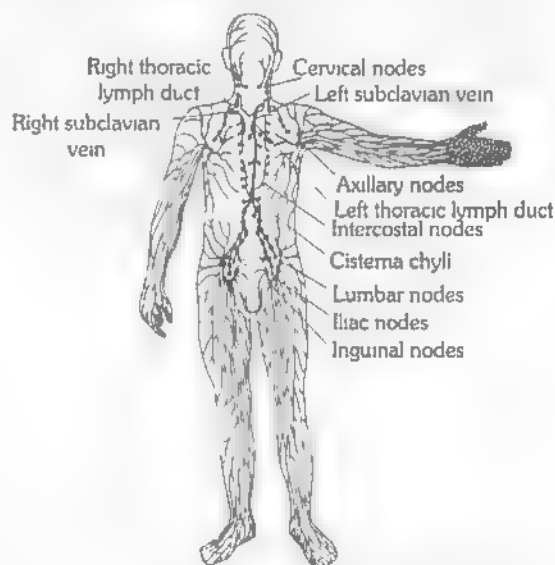
more widely scattered lymphocytes. Epithelial cells produce thymic hormone for maturation of T cells. Medulla also contain characteristic thymic (Hassall's) corpuscles, possibly, they are remnants of dying cells.

### Lymphatic system in human

**Lymph capillaries :** Small, thin, lined by endothelium resting on a basement membrane and fine whose one end is blind and other end unites to form lymphatic ducts. These are present almost throughout the body but are absent in brain, eyeball, spinal cord, internal ear, bone marrow etc. Lymph capillaries in the region of small intestine in villi are called "lacteals" which collect chyle which is milky white in colour due to absorbed fat. Lacteals help in the absorption of digested fat

**Lymphatic ducts or vessels :** Numerous, present in various parts of body. These vessels are like veins as they have all the three layers – tunica externa, tunica media and tunica interna, and are provided with watch pocket or semilunar valves but valves are more in number than veins. Valves are bicuspid.

**Flow of lymph in lymphatics :** Pulsations of lymph hearts in frog create sufficient force to maintain a steady flow of lymph in the lymphatic system. In mammals, the credit for maintaining onwards flow of lymph goes to (i) the "squeezing force" created by the skeletal muscles known as milking reaction (ii) the breathing movements of diaphragm and thoracic cage, (iii) mild peristalsis created by smooth muscles of the wall, of lymphatics themselves, and (iv) the pressure created by increasing amount of lymph in the lymphatics. Certain compounds like fats increase the rate of lymph flow and are called lymphata gogue. Blocking of lymph flow causes oedema.



**Fig : 5.3-17 Lymphatic system of mammals shown in man (ventral view)**

**Types of lymphatic ducts :** Two main types :

(1) **Right lymphatic duct :** It is the smallest lymphatic duct with the length of approximately 1.25 cm. Its one end is blind and other one opens into right subclavian vein at the junction of right internal jugular vein. It collects lymph from one-fourth of the body (right part of head, neck, thoracic cavity and right arm).



(2) **Left lymphatic duct/thoracic duct** : It is the longest lymphatic duct with the length of approximately 38-45 cm. It originates from cisterna chyli and empties into left subclavian vein. It collects lymph from three-fourth part of the body i.e. complete posterior part through cisterna chyli, left part of head, neck, thoracic cavity and left arms.

**Cisterna chyli/Receptaculum chyli** : It is a dilated sac like structure present below the diaphragm in lumbar region at the level of second lumbar vertebra. It collects lymph from posterior part of body i.e. abdomen, pelvic region and hind limbs and drains it in the left lymphatic duct.

It shows inflation and deflation due to the movement of diaphragm which is a passive movement. Hence, it is also called as passive lymphatic artery. It is also called as second heart.

**Lymph nodes or lymph glands** : These are the masses of lymphatic tissue and connective tissue (reticular tissue) and are located on the capillaries either solitary or in cluster. Where they are present solitary and in few number, such tissues are called diffused lymphatic tissues and where they are in clusters, they are called tonsils.

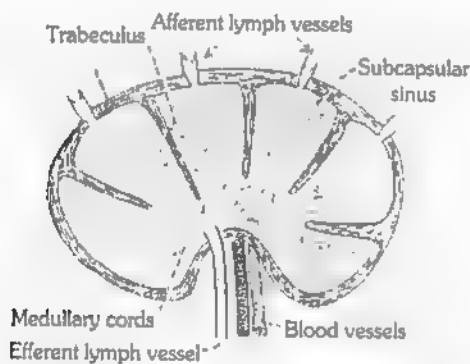


Fig : 5.3-18 Scheme to show some features of the structure of a lymph node

❑ **Lymphadenitis** : During infection, central part of follicle shows rapid division and formation of plasma cells. hence, this part is also called reaction centre. The inflammation of lymph nodes in such condition is called Lymphadenitis.

Some of the common lymph nodes are – Axillary nodes (in armpits), genital (Inguinal) nodes (in pubic region), cervical nodes (in neck region), intercostal nodes (in chest region), lumbar nodes (in lumbar region), iliac nodes (in pelvic region) and peyer's patches (in small intestine). Besides these lymphatic nodes, a number of them are also present near major blood vessels (arteries), specially dorsal aorta.

❑ **Tonsils** : Clusters of lymph nodes. They are very often called as policemen. Various tonsils are – Normal tonsils (in pharynx), adenoid tonsils (in nasopharynx), abdominal tonsils (in vermiform appendix) and policeman of intestine (in lamina propria of ileum). Adenoid tonsils are present upto 7 years of age, then they are degenerated. Their swelling is called adenoid. Inflammation of tonsils is called Tonsillitis.

❑ **Haemal lymph node** : In many animals some lymph nodes are found to possess red colour, due to the presence of blood in them. In man they are found in the retroperitoneal tissues and also in the mediastinum. Spleen may be regarded as the modified haemal lymph (haemolymph) node. Lymph nodes are located at intervals along its course.

#### Function of lymph nodes

(i) They produce and supply lymphocytes to the blood and as a supportive function the trabeculae carry blood vessels which supply the node.

(ii) They make screening of the lymph by means of phagocytic activity.

(iii) They serve a great defensive role against bacterial infections.

(iv) They temporarily stop the spread of cancer cells as those cells have to penetrate through the lymph vessels to the lymph nodes from where they spread in the body.

(v) They act as mechanical filters to resist the entrance of poisonous substances into circulation.

(vi) They carry out immunological responses. They help in elaboration of antibodies and in the development of immunity.

(vii) Lymph nodes produce  $\gamma$ globulin.

## T Tips & Tricks

- ✎ Lymphatic system in class amphibia is of open type.
- ✎ Lymph sinuses are the large spaces containing lymph. These are present in frog but absent in mammals
- ✎ Lymph heart – The heart which collects lymph.
- ✎ In frog, lymph hearts are two pairs – an anterior pair and a posterior pair which collect lymph from respective regions. There are no lymph hearts in mammals.
- ✎ The process of lymph formation is called Transudation.
- ✎ Spleen is called “first reservoir” of blood while liver is called “second reservoir” of blood.
- ✎ Spleen, liver and kidneys – all are called filter apparatus of blood.
- ✎ Diseases where there is more destruction of RBCs such as malaria, banti disease, there is enlargement of spleen called as splenomegaly
- ✎ In AIDS, there occurs generalised swelling of all lymph nodes.
- ✎ Spleen is absent in cyclostomes.
- ✎ Cardiology – Study of heart.
- ✎ Frank-Starling law – The increase in strength of contraction as a result of stretching the walls of ventricle is known as starling's law of the heart.
- ✎ Largest sized heart is found in Blue whale and in elephant among the terrestrial animals

- ✎ Papillary muscles of ventricles are found only in the heart of mammals.
- ✎ Valves in heart were first reported by Fabricius.
- ✎ World's first heart transplant was performed by Dr. Christian Barnard on 55-year old Louis Washkansky in Cape town South Africa in the year 1967.
- ✎ India's first heart transplant was conducted by cardiac surgeon Dr. P. Venu Gopal in a 42-year old man Mr. Devi Ram on 3<sup>rd</sup> August, 1994 at AIIMS, Delhi
- ✎ Myocardial Ischaemia – Deficient blood supply to heart muscle leading to angina pectoris
- ✎ Angina pectoris – Severe but temporary heart pain of short duration which is usually felt in front of the chest and may pass into the arms specially left sided.
- ✎ Coronary thrombosis – Formation of blood clot in coronary arteries of heart causing death of tissue and leading to heart attack or MI.
- ✎ Coronary sclerosis – Narrowing of coronary arteries leading to severe chest pain (Angina pectoris)
- ✎ Rheumatic heart Disease (RHD) – Defects in heart valve due to toxins produced by throat infection caused by streptococcus leading to rheumatic fever and arthritis.
- ✎ Coronary angiography – X-ray of the arteries, supplying the heart, after injecting them with radio-opaque material
- ✎ Vasa vasorum are blood vessels which supply blood to the walls of great blood vessels.
- ✎ Ringer's solution is solution of chlorides of sodium, potassium, and calcium, discovered by Ringer in 1887
- ✎ Artificial pacemaker is an electronic device with lithium halide battery, it was first developed by Greatbach and Chardack (1960).
- ✎ Splenic vein with maximum free Hb
- ✎ Both pulmonary Aorta and a pair of umbilical artery (Human foetus) carry deoxygenated blood.
- ✎ Nereis among annelids and amphioxus among chordates have no heart.
- ✎ Ampullary hearts are found in crustaceans, insects and cephalopods.
- ✎ Pulsating hearts are found in annelids and mollusca
- ✎ The heart of cockroach contracts with the help of alary muscles at a rate of 50 times/minute.
- ✎ In Unio (fresh water mussel), rectum passes through the heart and the wastes are discharged into the pericardial cavity by Keber's organ (also called pericardial gland)
- ✎ Circulatory system develops from the mesoderm in vertebrates.
- ✎ **Gubernaculum cordis** : White fibrous band which attaches apex of lizard heart to pericardium.
- ✎ Blood pressure was first measured by Halls in 1732.
- ✎ ECG was invented by Einthoven (1906).
- ✎ Bundle of His was discovered by a German Physiologist William His Jr. (1893).

✎ **Plethysmograph** : Device for finding variations in size of a part due to variation in amount of blood passing through or contained in the part.

✎ **Wenckebach's Phenomenon** : A form of incomplete heart block in which there is progressive lengthening of P-R interval.

✎ **Diapedesis** : Passage of blood cells esp. leucocytes by amoeboid movements through the unruptured wall of a capillary vessel.

✎ S.A. node is the pacemaker and A.V. node is the pace setter of heart



## Ordinary Thinking

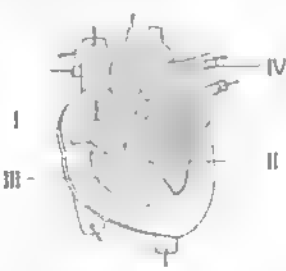
### Objective Questions

#### Structure and function of heart

1. The blood returning to the heart from lungs via pulmonary vein has more [AIIMS 1992; MP PMT 1994]
  - (a) RBC per ml of blood
  - (c) Haemoglobin per ml of blood
  - (c) Oxygen per ml of blood
  - (d) Nutrient per ml of blood
2. Systemic heart refers to [CBSE PMT 2003]
  - (a) The two ventricles together in humans
  - (b) The heart that contracts under stimulation from nervous system
  - (c) Left auricle and left ventricle in higher vertebrates
  - (d) Entire heart in lower vertebrates
3. The problem of electrical discontinuity caused in the normal heart by the connective tissue separating the atria from the ventricles is solved by [J & K CET 2012]
  - (a) Coordinating electrical activity in the atria with electrical activity in the ventricles by connecting them via the bundle of His
  - (b) Having the A-V node function as a secondary pacemaker
  - (c) Having an ectopic pacemaker
  - (d) Coordinating electrical activity in the atria with electrical activity in the ventricles by connecting them via the vagus nerve
4. What is total diastolic time of ventricle in cardiac cycle [GUJCET 2015]
 

(a) 0.30 second	(b) 0.40 second
(c) 0.50 second	(d) 0.10 second
5. Which one of the following is a matching pair [AIIMS 2003, 08; AMU (Med.) 2012]
  - (a) Lub - sharp closure of AV valves at the beginning of ventricular systole
  - (b) Dup - sudden opening of semilunar valves at the beginning of ventricular diastole
  - (c) Pulsation of the radial artery-valves in the blood vessels
  - (d) Initiation of the heart beat Purkinje fibres
6. In the heart of mammals the bicuspid valve (mitral valve) is situated between [NCERT; Manipal 1995; BHU 1999; VITEEE 2003; MP PMT 2005, 06; AFMC 2009]
  - (a) Left auricle and left ventricle
  - (b) Post caval and right caval
  - (c) Right auricle and left auricle
  - (d) Right ventricle and pulmonary aorta

7. The auriculo-ventricular node in human heart was discovered by [JIPMER 1994]  
 (a) Hiss (b) Lewis  
 (c) Ringer (d) William Harvey
8. Ventricular diastole occurs due to a/an [AIIMS 2012]  
 (a) Organ system (b) Cell organelle  
 (c) Tissue (d) Organ
9. Nature of valves in the heart is [CPMT 1992]  
 (a) Membranous (b) Muscular  
 (c) Tendinous (d) Ligamentous
10. Which of the following is the correct statement about the circulatory system of cockroach [CPMT 2001]  
 (a) It is closed type of circulatory system  
 (b) It is a complicated type of circulatory system  
 (c) It takes place without the participation of tissue  
 (d) It has 13 chambered heart and in each segment one pair of ostia are present
11. The T-wave in an ECG represents [KCET 2015]  
 (a) Depolarisation of ventricles  
 (b) Electrical excitation of atria  
 (c) Beginning of systole  
 (d) Return of the ventricles from excited state
12. The volume of blood that enters into the aorta with each ventricular systole is called [KCET 2012]  
 (a) Cardiac cycle (b) Stroke volume  
 (c) Cardiac output (d) Vital capacity
13. Epinephrine is secreted by [AFMC 2008; Kerala PMT 2012]  
 (a) Adrenal medulla and increases the heart rate  
 (b) Adrenal medulla and decreases the heart rate  
 (c) Adrenal cortex and increases the heart rate  
 (d) Adrenal cortex and decreases the heart rate
14. Heart beat can be initiated by [NCERT; CBSE PMT 1999, 2002; AFMC 2000; Odisha JEE 2004; KCET 2012]  
 Or  
 The cardiac pacemaker in a patient fails to function normally. The doctors find that an artificial pacemaker is to be grafted in him. It is likely that it will be grafted at the site of [CBSE PMT 2004]  
 (a) Sino-auricular node (b) Atrio-ventricular node  
 (c) Sodium ion (d) Purkinje's fibres
15. The other term for heart attack is [BHU 2012]  
 (a) Coronary thrombosis (b) Myocardial infarction  
 (c) Cardiac arrest (d) Ischaemia
16. Read the statements regarding the cardiac system and choose the right option  
 A. Human heart is an ectodermal derivative  
 B. Mitral valve guards the opening between the right atrium and left ventricle  
 C. SAN is located on the left upper corner of the right atrium  
 D. Stroke volume  $\times$  Heart rate = Cardiac output [NCERT; BHU 2004; AMU (Med) 2005; Kerala PMT 2012]  
 (a) A alone is correct  
 (b) A and B alone are correct  
 (c) B and C alone are correct  
 (d) D alone is correct  
 (e) B and D above are correct
17. Oxygenated blood is carried by [AFMC 1995, 2000, 10; MP PMT 1998]  
 Or  
 Blood vessels carrying blood from lungs to heart [MP PMT 1994; MHCET 2000; JIPMER 2002]  
 (a) Pulmonary vein (b) Pulmonary artery  
 (c) Renal vein (d) Hepatic portal vein
18. Purkinje's fibres are special types of [BHU 1995, 2000; MP PMT 2012]  
 (a) Muscle fibres located in heart  
 (b) Nerve fibres located in cerebrum  
 (c) Connective tissue fibres joining one bone to another bone  
 (d) Sensory fibres extending from retina into optic nerve
19. The tricuspid valve is present at the origin of [CBSE PMT 1993]  
 (a) Carotid arch (b) Pulmonary arch  
 (c) Truncus arteriosus (d) Systemic arch
20. The atrio-ventricular valves of the heart is prevented from turning inside out by tough strands of connective tissue is called as [CBSE PMT 1993]  
 (a) Tendinous cords (b) Tricuspid  
 (c) Pocket valve (d) Mitral valve
21. The pericardium and the pericardial fluid help in [DPMT 1993]  
 (a) Protecting the heart from friction, shocks and keeps it moist  
 (b) Pumping the blood  
 (c) Receiving the blood from various parts of the body  
 (d) None of the above
22. The thread like tendons of papillary muscles inserted upon the flaps of tricuspid and bicuspid valves are [AIIMS 2009]  
 (a) Chordae tendinae (b) Yellow elastin fibres  
 (c) Reticulate fibres (d) Collagen fibres
23. Blood leaving liver and moving to the heart has usually high concentration of [CPMT 2005]  
 (a) Urea (b) Bile  
 (c) Glucose (d) Erythrocytes
24. Circulatory system does not help in [Odisha JEE 2012]  
 (a) Transport of respiratory gases  
 (b) Transport of hormones  
 (c) Transport of food materials  
 (d) Transfer of impulses
25. The volume of blood each ventricle pumps out during a cardiac cycle is about [Kerala PMT 2011]  
 (a) 70 ml (b) 5000 ml  
 (c) 7 l (d) 1200 ml  
 (e) 40 ml
26. Which one of the statement is correct with reference to the circulation of blood in a mammal  
 (a) Left auricle receives oxygenated blood from the lungs  
 (b) Pulmonary artery returns oxygenated blood from the lungs to the left auricle  
 (c) Pulmonary vein carries venous blood from right auricle to lungs  
 (d) Venous blood is returned to the left auricle

27. The typical Lubb-Dup sounds heard in the heart beat of a healthy person are due to [CBSE PMT 1994; KCET 1994; MP PMT 2011; WB JEE 2012; AIPMT 2015]  
 (a) Closing of the tricuspid and bicuspid valve  
 (b) Blood flow through the aorta  
 (c) Closing of the tricuspid and semilunar valves  
 (d) Closing of the semilunar valves
28. The increase in blood flow to heart stimulates secretion of [MHCET 2015]  
 (a) Renin (b) Oxytocin  
 (c) Antidiuretic hormone (d) Atrial natriuretic factor
29. Pace maker (S.A. Node) of the heart is situated [NCERT; MP PMT 1994, 95; BVP 2000; AIIMS 2004; Pb PMT 2004; Wardha 2005; DPMT 2006]  
 (a) In wall of right atrium close to eustachian valve  
 (b) On intra-auricular septum  
 (c) On inter-ventricular septum  
 (d) In wall of left atrium close to the opening of pulmonary veins
30. During systole [NCERT; MP PMT 1994]  
 (a) Auricles and ventricles contract simultaneously  
 (b) Auricles and ventricles contract separately  
 (c) Only auricles contract  
 (d) Only ventricles contract
31. Right auricle of mammalian heart receives blood from [MP PMT 1994, 96]  
 (a) Sinus venosus (b) Pulmonary veins  
 (c) Precavals (d) Pre and postcavals
32. During ventricular diastole [MP PMT 1994; PET (Pharmacy) 2013]  
 (a) The auricles relax (b) The heart contracts  
 (c) The heart pumps blood (d) The ventricles relax
33. The following figure shows human heart. Which labelled structure represents the bundle of His [NCERT]  
 (a) IV  
 (b) III  
 (c) II  
 (d) I
- 
34. In humans, blood passes from the post caval to the diastolic right atrium of heart due to [CBSE PMT 2008]  
 (a) Stimulation of the sino auricular node  
 (b) Pressure difference between the post caval and atrium  
 (c) Pushing open of the venous valves  
 (d) Suction pull
35. Open circulatory system is present in [NCERT; KCET 1999; Kerala PMT 2008]  
 (A) Arthropods (Insects) (B) Annelids  
 (C) Chordates (D) Molluscs  
 (a) C only (b) C and B  
 (c) A and B (d) D only  
 (e) A and D
36. Blood enters the heart because muscles of the [Odisha JEE 2009]  
 (a) Atrium contracts (b) Atrium relaxes  
 (c) Ventricle relaxes (d) Ventricle contracts
37. The function of vagus nerve innervating the heart is to [DUMET 2009]  
 (a) Initiate the heart beat (b) Reduce the heart beat  
 (c) Accelerate the heart beat (d) Maintain constant heart beat
38. An oval depression called fossa ovalis is seen on [Kerala PMT 2009]  
 (a) Inter atrial septum  
 (b) Inter ventricular septum  
 (c) Right auriculo-ventricular septum  
 (d) Left auriculo-ventricular septum  
 (e) Papillary muscles
39. Which of the following statements is related to Starling's law of heart [WB JEE 2008]  
 (a) Greater the stroke volume greater is the heart rate  
 (b) Greater the initial length of the cardiac muscle fibre, more is the force of contraction of heart  
 (c) Greater the minute volume, greater is the heart rate  
 (d) Lesser the length of cardiac muscle fibre greater is the force of contraction of heart
40. Heart beats are accelerated by [AFMC 1994]  
 (a) Cranial nerves and acetylcholine  
 (b) Sympathetic nerves and acetylcholine  
 (c) Cranial nerves and adrenaline  
 (d) Sympathetic nerves and epinephrine
41. JG cells, under low glomerular blood flow, release [Kerala PMT 2008]  
 (a) Angiotensin I (b) Angiotensin II  
 (c) Renin (d) Aldosterone  
 (e) ADH
42. The triangular sac like structure which receives blood through the vena cava in frog is [Kerala PMT 2012]  
 Or  
 Which of the following structure is absent in rabbit's heart [RPMT 1995]  
 (a) Ventricle (b) Sinus venosus  
 (c) Hepatic portal system (d) Conus arteriosus  
 (e) Left auricle
43. Which of the following parts of heart first receives deoxygenated blood [BHU 2008]  
 Or  
 Tricuspid valve is present in [Odisha JEE 2010]  
 (a) Right ventricle (b) Left auricle  
 (c) Right auricle (d) Left ventricle
44. The duration of cardiac cycle is [NCERT; J & K CET 2008; WB JEE 2009, 10; BHU 2012]  
 (a) 0.8 sec (b)  $0.8 \mu\text{sec}$   
 (c) 0.08 sec (d) 0.008 sec
45. 'Bundle of His' is a part of which one of the following organs in humans [NCERT; CBSE PMT (Pre.) 2011]  
 (a) Pancreas (b) Brain  
 (c) Heart (d) Kidney
46. First heart sound occurs at [RPMT 1999; CBSE PMT 2000; BHU 2008]  
 (a) Opening of semilunar valve (b) Closing of semilunar valve  
 (c) Onset of auricular systole (d) Sudden closure of A.V. valves
47. An artificial pace-maker is implanted subcutaneously and connected to the heart in patients [AIIMS 2004, 07]  
 (a) Having 90% blockage of the three main coronary arteries  
 (b) Having a very high blood pressure  
 (c) With irregularity in the heart rhythm  
 (d) Suffering from arteriosclerosis
48. When the heart beat increases the condition is called  
 (a) Bradycardia (b) Tachycardia  
 (c) Leucopenia (d) Cardiac arrest
49. If due to some injury the chordae tendinae of the tricuspid valve of the human heart is partially non-functional, what will be the immediate effect [CBSE PMT (Pre.) 2010]  
 (a) The flow of blood into the pulmonary artery will be reduced  
 (b) The flow of blood into the aorta will be slowed down  
 (c) The 'pacemaker' will stop working  
 (d) The blood will tend to flow back into the left atrium



50. Human heart is enclosed in a double walled sac called [HP PMT 2005]  
 (a) Peritone (b) Pericardium  
 (c) Pericardial sinus (d) Perineural sinus
51. 'Heart of Heart' is [NCERT; BHU 2005, 08]

Or

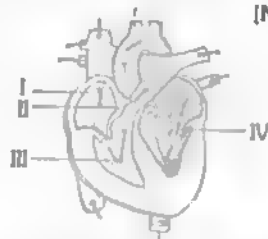
Pace maker of the heart is

[CPMT 1995, 98; BHU 2006; WB JEE 2011]

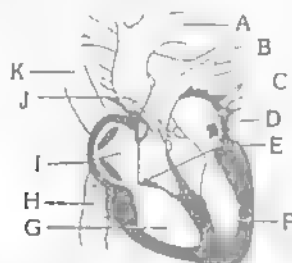
- (a) SA node (b) AV node  
 (c) Bundle of His (d) Purkinje fibres
52. Spiral valve is present in [MH CET 2000]  
 (a) Right auricle (b) Left auricle  
 (c) Right ventricle (d) Truncus arteriosus
53. Which one is the correct route through which pulse making impulse travels in the heart [NCERT; KCET 1994, 2004, 05; CBSE PMT 1995; Kerala PMT 2007; WB JEE 2011]  
 (a) SA node → Purkinje fibres → Bundle of His → AV node → Heart muscles  
 (b) AV node → SA node → Purkinje fibres → Bundle of His → Heart muscles  
 (c) AV node → Bundle of His → SA node → Purkinje fibres → Heart muscles  
 (d) SA node → AV node → Bundle of His → Purkinje fibres → Heart muscles

54. The given diagram shows the human heart. Which site represents the generation of action potential in human heart [NCERT]

- (a) IV  
 (b) III  
 (c) II  
 (d) I



55. See the figure of the vertical section of human heart given below certain parts have been indicated by letters. Select the correct answer in which these letters have been correctly paired with parts they indicate [NCERT]



- (a) A - Aorta; B - Superior vena cava, C - Inferior vena cava; D - Left ventricle; E - Semilunar valves; F - Left auricle; G - Right auricle; H - Pulmonary artery; I - Right ventricle; J - Tricuspid valves; K - Pulmonary vein  
 (b) A - Aorta; B - Superior vena cava, C - Inferior vena cava; D - Right ventricle; E - Tricuspid and Mitral valves; F - Right auricle; G - Left auricle; H - Pulmonary vein, I - Left ventricle; J - Semilunar valves; K - Pulmonary artery  
 (c) A - Aorta; B - Pulmonary artery, C - Pulmonary vein; D - Left auricle; E - Tricuspid and Mitral valves; F - Left ventricle; G - Right ventricle; H - Inferior vena cava; I - Right auricle; J - Semi lunar valves; K - Superior vena cava  
 (d) A - Aorta; B - Pulmonary vein, C - Pulmonary arteries; D - Left ventricle; E - Semilunar valves; F - Left auricle; G - Right auricle; H - Superior vena cava; I - Right ventricle; J - Tricuspid valves; K - Inferior vena cava

56. Which of the following statements is false [Manipal 1995]

- (a) Blood from the right side of the heart is carried to the lungs by the pulmonary artery  
 (b) The term *pleura* refers the double layered covering of the kidney  
 (c) Pancreas is both an exocrine and endocrine gland  
 (d) Scurvy is caused by the deficiency of vitamin C

57. The pace-setter in the heart is called [CBSE PMT 1994]

- (a) Purkinje fibres  
 (b) Sino-arterial node (SAN)  
 (c) Papillary muscle  
 (d) Atrio-ventricular node (AVN)

58. Largest heart is found in [AFMC 1996]

- (a) Elephant (b) Giraffe  
 (c) Crocodile (d) Lion

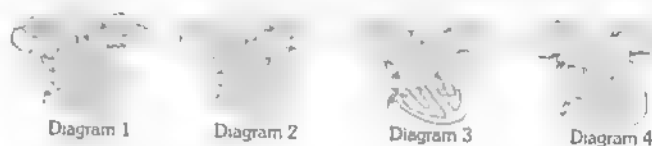
59. Average cardiac output is [MP PMT 1996; WB JEE 2012]

- (a) 4 litres per minute (b) 6.3 litres per minute  
 (c) 5.3 litres per minute (d) 7.3 litres per minute

60. Alary muscle is associated with [CPMT 2002; RPMT 2005]

- (a) Heart and circulation  
 (b) Malpighian tubules and excretion  
 (c) Trachea and respiration  
 (d) None of the above

61. Which diagram shows the correct blood circulation [NCERT; GUJCET 2014]

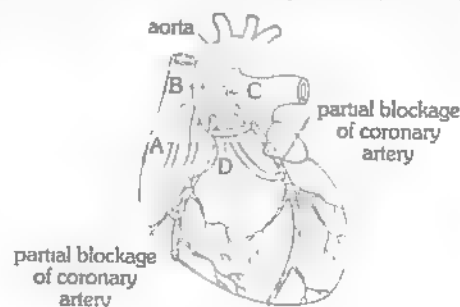


- (a) Diagram 1 (b) Diagram 2  
 (c) Diagram 3 (d) Diagram 4

62. The chamber of human heart, which has thickest wall [JIPMER 1994; Kerala PMT 2004; WB JEE 2010]

- (a) Right atrium (b) Left atrium  
 (c) Right ventricle (d) Left ventricle  
 (e) None of these

63. Which tube in the given figure of a heart correctly represents the result of a successful coronary bypass operation [NCERT]



- (a) C  
 (b) B  
 (c) D  
 (d) A

64. The given figure indicates three stages in the cardiac cycle

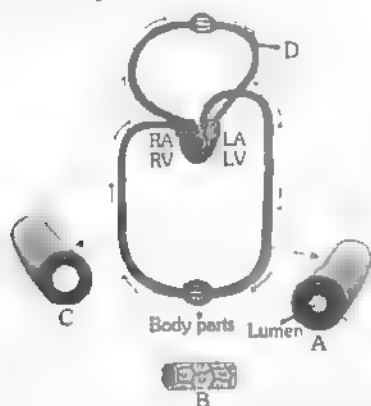


Choose the correct sequence

[NCERT]

- (a) 3, 1, 2 (b) 2, 1, 3  
(c) 1, 2, 3 (d) 2, 3, 1

65. Figure shows blood circulation in humans with labels A to D. Select the option which gives correct identification of label and functions of the part



[NEET (Karnataka) 2013]

- (a) B – Capillary – thin without muscle layers and well two cell thick  
(b) C – Vein – thin walled and blood flows in jerks/spurts  
(c) D – Pulmonary vein – takes oxygenated blood to heart  $PO_2 = 95 \text{ mm Hg}$   
(d) A – Artery – thick walled and blood flows evenly
66. The wall of heart is made up of [MP PMT 1997]  
(a) Epicardium (b) Myocardium  
(c) Endocardium (d) All of the above
67. Heart beats are affected by [MP PMT 1998]  
(a) Carbon dioxide (b) Oxygen  
(c) Vagus nerve (d) All the above
68. Heart beat originates from [NCERT; CMC Vellore 1993; MP PMT 1998; CBSE PMT 2002]  
(a) Pacemaker (b) Cardiac muscles  
(c) Left atrium (d) Right ventricle
69. In the evolution of animals a heart to pump the blood is found for the first time in [Kerala CET 2003]  
(a) Annelids (b) Roundworms  
(c) Arthropods (d) Flat worms
70. Which of the following is different from others in absence of muscular coat [CPMT 1999; JIPMER 2001]  
(a) Veins (b) Arteries  
(c) Capillaries (d) Arterioles
71. In order for the blood to flow from right ventricle to left ventricle in mammalian heart, it must flow through [DUMET 2010]  
(a) Right ventricle, pulmonary arteries, Lungs, Pulmonary veins, Left atrium  
(b) Right ventricle, Pulmonary veins, Lungs, Pulmonary arteries, Left atrium  
(c) Right ventricle, Right atrium, Lungs, Pulmonary veins, Left atrium  
(d) Right ventricle, Systemic aorta, Lungs, Pulmonary veins, Left atrium

72. The heart of a crocodile consists of [KCET 2002; RPMT 2002; AIEEE Pharmacy 2003; BVP 2004]

- (a) A single auricle and two ventricles  
(b) Two auricles and a single ventricle  
(c) Two auricles and two ventricles  
(d) A single auricle and a single ventricle

73. The post-caval is constituted by [Pune CET 1998]

- (a) Renal, gonadal and hepatic  
(b) Renal and gonadal  
(c) Gonadal and hepatic  
(d) Hepatic and renal

74. The pre-caval vein is formed of [Pune CET 1998]

- (a) External jugular and innominate  
(b) Innominate and subclavian  
(c) External jugular, innominate and subclavian  
(d) External jugular and subclavian

75. The post-caval vein collects blood from [Pune CET 1998]

- (a) Hind limbs  
(b) Hind limbs and organs of the body cavity  
(c) Body cavity organs  
(d) Renal organs

76. The pre-caval veins collect blood from [Pune CET 1998]

- (a) Trunk and hind limbs (b) Fore limbs and hind limbs  
(c) Head and fore limbs (d) Head and hind limbs

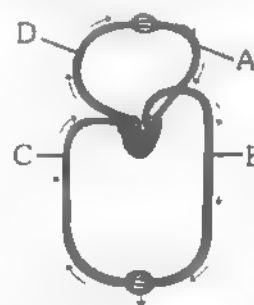
77. The two branches of the iliac artery are [Pune CET 1998]

- (a) Femoral and renal  
(b) Femoral and sciatic  
(c) Vesiculo-epigastric and femoral  
(d) Renal and sciatic

78. The unpaired systemic branch is [Pune CET 1998]

- (a) Coeliaco-mesentric (b) Renal artery  
(c) Iliac (d) Vesiculo-epigastric

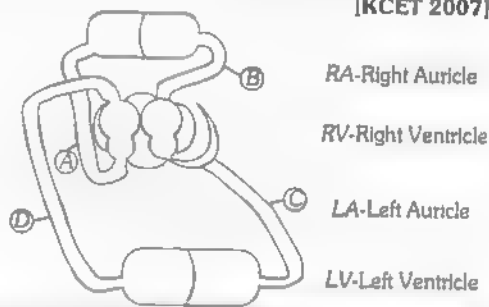
79. Figure shows schematic plan of blood circulation in humans with labels A to D, Identify the label and give its function/s



[NEET 2013]

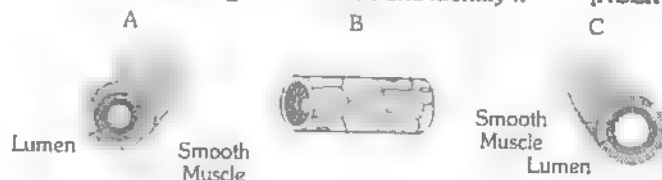
- (a) D-Dorsal aorta-takes blood from heart to body parts,  $PO_2 = 95 \text{ mm Hg}$   
(b) A-Pulmonary vein-takes impure blood from body parts,  $PO_2 = 60 \text{ mm Hg}$   
(c) B-Pulmonary artery-takes blood from heart to lungs,  $PO_2 = 90 \text{ mm Hg}$   
(d) C-Vena Cava-takes blood from body parts the right auricle,  $PCO_2 = 45 \text{ mm Hg}$

80. Inter-auricular septum in the embryonic stages has a/an [AFMC 1997]  
 (a) Foramen ovale (b) Fenestra ovalis  
 (c) Fenestra rotunda (d) Inter-auricular aperture
81. Bundle of His is a network of [NCERT; CBSE PMT 2003; MP PMT 2004, 07]  
 (a) Nerve fibres found throughout the heart  
 (b) Muscle fibres distributed throughout the heart walls  
 (c) Muscle fibres found only in the ventricle wall  
 (d) Nerve fibres distributed in ventricles
82. Which is correct about veins [BHU 2000]  
 (a) Valves are absent  
 (b) Carry blood towards heart  
 (c) Always carry oxygenated blood  
 (d) Always carry deoxygenated blood
83. In frog heart, there are cardiac muscles which consist of fibres called [BHU 2006]  
 (a) Purkinje fibres (b) Myonemes  
 (c) Telodendria (d) Columnae carnae
84. What is correct about sinus venosus [MP PMT 2000]  
 (a) It is situated on dorsal surface of rabbit heart  
 (b) It is situated ventrally in frog heart  
 (c) It sends blood to dorsal aorta  
 (d) It opens into right auricle
85. In amphibia, the heart has [AFMC 2001]  
 (a) Two auricles and two ventricle  
 (b) Two auricles and one ventricle  
 (c) One auricle and two ventricles  
 (d) One auricle and one ventricle
86. Atherosclerosis refers to the ailment of [MP PMT 2001]  
 (a) Lungs (b) Heart  
 (c) Kidney (d) Liver
87. In rabbit oxygenated blood flows from [RPMT 2001]  
 (a) Left auricle to left ventricle during auricular systole  
 (b) Right auricle to right ventricle during ventricular systole  
 (c) Right ventricle to aorta during ventricular systole  
 (d) Pulmonary vein to left auricle during auricular systole
88. The innervation of heart is primarily meant for [MP PMT 2013]  
 (a) Initiation of heart beat (b) Regulation of heart beat  
 (c) Activation of pace maker (d) Release of acetylcholine
89. Impulse originating from sinu-atrial node are transmitted to the [JIPMER 2002]  
 (a) Atrio-ventricular node (b) Bundle of His  
 (c) Pacemaker (d) Purkinje system
90. Below normal heart beat is called [AFMC 2002]  
 (a) Bradycardia (b) Tachycardia  
 (c) Hyperpiesis (d) All of these
91. Heart of elephant is [CPMT 2002; DPMT 2004, 05]  
 (a) Neurogenic (b) Myogenic  
 (c) Both (a) and (b) (d) None of these
92. Thoracic duct in humans is associated with [BHU 2002]  
 (a) Aorta (b) Hepatic duct  
 (c) Purkinje fibre (d) Innominate vein
93. How many double circulations are normally completed by the human heart, in one minute [NCERT; KCET 2006]  
 (a) Eight (b) Sixteen  
 (c) Seventy two (d) Thirty six
94. The blood vascular system of mammals is known as double vascular system because [AFMC 1995]  
 (a) A group of veins carry oxygenated and other group conduct deoxygenated blood  
 (b) Oxygenated blood runs from heart to different organs by one set of veins while deoxygenated blood runs from heart to lung by another set  
 (c) The two different systems never meet  
 (d) All of the above
95. In connection with circulatory system, valves are present [CBSE PMT 1995]  
 (a) Not only in heart and blood vessels of vertebrates and invertebrates, but in vertebrate lymphatics as well  
 (b) Vertebrate heart only  
 (c) Vertebrate heart and invertebrate hearts only  
 (d) Vertebrate hearts, invertebrate hearts and their blood vessels
96. In the below given diagram which blood vessel represents vena cava [KCET 2007]



Blood vessel

1. The study of blood vessels is termed as [MHCET 2015]  
 (a) Angiology (b) Cardiology  
 (c) Haematology (d) Histology
2. Serotonin in the blood [CBSE PMT 1992]  
 (a) Relaxes blood vessels (b) Prevents clotting of blood  
 (c) Helps in clotting of blood (d) Constricts blood vessels
3. The thickening of walls of arteries is called [BHU 2012]  
 (a) Arteriosclerosis (b) Arthritis  
 (c) Aneurysm (d) Both (b) and (c)
4. The pulse beat is measured by the  
 (a) Artery (b) Capillary  
 (c) Vein (d) None
5. Carotid artery carries [MP PMT 1995; AFMC 2005]  
 (a) Impure blood from brain  
 (b) Oxygenated blood to anterior region of body or to brain  
 (c) Impure blood to kidney  
 (d) Oxygenated blood to heart
6. See the following blood vessels and identify it [NCERT]



	A	B	C
(a)	Vein	Capillary	Artery
(b)	Artery	Capillary	Vein
(c)	Capillary	Artery	Vein
(d)	Artery	Vein	Capillary

7. Which artery is absent in frog [MP PMT 2000]  
Or

The diaphragm is supplied with blood by

[CPMT 1992; RPMT 1995; MP PMT 1995]

- (a) Cardiac artery (b) Phrenic artery  
(c) Lingual artery (d) Lumbar artery
8. The blood vessel which supplies oxygenated blood to cardiac tissue is [WB JEE 2012]  
(a) Coronary artery (b) Coronary vein  
(c) Coronary sinus (d) Pulmonary vein
9. Blocking of arteries due to deposition of fats and calcium is called [MH CET 2002; Kerala PMT 2009]

Or

Which one of following is not related with bone disorder

[WB JEE 2016]

- (a) Arteriosclerosis (b) Atherosclerosis  
(c) Emphysema (d) Heart syndrome
10. Regarding blood circulation, it may be said that in *Pheretima* the dorsal vessel is a [Pb. PMT 1999]  
(a) Collecting vessel in first two segments and distributing vessel in other  
(b) Distributing vessel in first five segments and collecting vessel in other  
(c) Collecting vessel in first thirteen segments and distributing vessel in intestinal region  
(d) Distributing vessel in first thirteen segments and collecting vessel in intestinal region
11. Arteries are best defined as the vessels which [NCERT; Odisha JEE 2009; CBSE PMT (Pre.) 2011]  
(a) Carry blood from one visceral organ to another visceral organ  
(b) Supply oxygenated blood to the different organs  
(c) Carry blood away from the heart to different organs  
(d) Break up into capillaries which reunite to form a vein
12. Fastest distribution of some injectible material/medicine and with no risk of any kind can be achieved by injecting it into the [NCERT; CBSE PMT (Mains) 2010]  
(a) Muscles (b) Arteries  
(c) Veins (d) Lymph vessels
13. Which of the following vein has least amount of urea [CPMT 1992, 93; HPMT 2005]  
(a) Pulmonary vein (b) Hepatic portal vein  
(c) Hepatic vein (d) Renal vein
14. The exchange of materials between blood and interstitial fluid is by [Odisha JEE 2009]  
(a) Arterioles (b) Arteries  
(c) Capillaries (d) Veins
15. Which one of the following is incorrect for 'atherosclerosis' [WB JEE 2012]  
(a) Constriction of arterial lumen reduces the blood flow  
(b) Loss of dilation ability of the arterial wall and its rupture  
(c) Cholesterol deposition at the inner wall of the artery  
(d) Proliferation of the vascular muscles

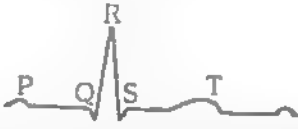
16. In closed circulatory system blood is enclosed by [Odisha JEE 2009]  
(a) Tubes (b) Ducts  
(c) Valves (d) Vessels

17. The structure of which of the following consist of a layer of single cell thickness [GUJCET 2007]  
(a) Blood capillary (b) Artery  
(c) Venule (d) Arteriole

### Blood pressure, ECG

1. In a standard ECG which one of the following alphabets is the correct representation of the respective of the human heart [NCERT; Kerala PMT 2007; CBSE PMT 2009]  
(a) R – repolarisation of ventricles  
(b) S – start of systole  
(c) T – end of diastole  
(d) P – depolarization of the atria
2. Sphygmomanometer measure [BHU 1999; AIIMS 2000; DPMT 2003; Odisha JEE 2010]  
(a) Nerve conduction rate (b) Heart beat rate  
(c) Blood pressure (d) Pulse rate
3. Increase in blood pressure is due to [Odisha JEE 2011]  
(a) Hypertension (b) Hypotension  
(c) Hyperglycemia (d) Hypochromia
4. ECG records [NCERT; BVP 2003]  
(a) Electric current of the body  
(b) Potential differences  
(c) Pulse rate  
(d) Quantity of blood pumped per minute
5. QRST is related with [MP PMT 2011]  
(a) Ventricular contraction or depolarization  
(b) Auricular contraction  
(c) Auricular relaxation  
(d) Cardiac cycle
6. Choose the correct statement [Kerala PMT 2012]  
(a) The T-wave in an ECG represents excitation of ventricles  
(b) The sum of P and T waves in a given time period can determine the heart beat rate of an individual  
(c) The end of the P-wave marks the end of the systole  
(d) In a standard ECG, a person is connected to the machine with three electrical leads  
(e) In a normal ECG, the highest peak is represented by 'S'
7. Fall in blood pressure due to loss of blood is soon restored because the [AIEEE Pharmacy 2003]  
(a) Blood vessels dilate  
(b) Blood cells decrease in number  
(c) Heart beat is increased  
(d) Heart beat is decreased
8. If the heart sound recording and ECG recordings are superimposed then the first heart sound would occur [AMU (Med.) 2009]  
(a) At the P wave  
(b) Just after the P wave  
(c) Just before the QRS complex  
(d) Just after the QRS complex



9. Blood pressure in the mammalian aorta is maximum during [AIPMT (Cancelled) 2015]  
 (a) Diastole of the right ventricle  
 (b) Systole of the left ventricle  
 (c) Diastole of the right atrium  
 (d) Systole of the left atrium
10. In a typical heart, if EDV is 120ml of blood and ESV is 50ml of blood, the stroke volume (SV) is [NCERT; KCET 2011]  
 (a)  $120 - 50 = 70\text{ml}$  (b)  $120 + 50 = 70\text{ml}$   
 (c)  $120 \times 50 = 6000\text{ml}$  (d)  $120 + 50 = 2.4\text{ml}$
11. The carotid labyrinth of frog is concerned with the control of [MH CET 2000]  
 (a) Temperature (b) Blood sugar  
 (c) Blood pressure (d) Blood composition
12. Blood pressure increases and heart rate decreases in response to [AIIMS 2001]  
 (a) Exercise (b) Haemorrhage  
 (c) Exposure to high altitude (d) Increased intracranial pressure
13. Which one of the following statement is correct regarding blood pressure [NCERT; CBSE PMT (Pre.) 2011]  
 (a) 190/110 mmHg may harm vital organs like brain and kidney  
 (b) 130/90 mmHg is considered high and requires treatment  
 (c) 100/55 mmHg is considered and ideal blood pressure  
 (d) 105/50 mmHg makes one very active
14. Deficiency of which of the following causes obesity, low plasma  $\text{Na}^+$ , high  $\text{K}^+$  and increased blood pressure [CPMT 1999; JIPMER 2001]  
 (a) Growth hormone (b) Adrenaline  
 (c) Cortisol (d) Thyroxine
15. During systole of ventricle [MP PMT 1995]  
 (a) Blood enters the heart (b) Blood leaves the heart  
 (c) Blood leaves the ventricle (d) Blood enters lungs
16. We feel sleepy just after taking meals because [CPMT 1996]  
 (a) Blood pressure increases (b) Blood pressure decreases  
 (c) Body weight increases (d) We feel lethargic
17. During diastole [MP PMT 1996]  
 (a) Blood enters lungs (b) Blood leaves the ventricle  
 (c) Blood leaves the heart (d) Blood enters the heart
18. If the systolic pressure is 120 mm Hg and diastolic pressure is 80 mm Hg, the pulse pressure is ..... [MHCET 2006; WB JEE 2010; KCET 2010]  
 (a)  $120 \times 80 = 9600\text{ mm Hg}$  (b)  $120 + 80 = 200\text{ mm Hg}$   
 (c)  $120 - 80 = 40\text{ mm Hg}$  (d)  $\frac{120}{80} = 1.5\text{ mm Hg}$
19. The diagram given here is the standard ECG of a normal person. The P-wave represents the
- 
- [CBSE PMT (Mains) 2011; NEET 2013]
- (a) End of systole  
 (b) Contraction of both the atria  
 (c) Initiation of the ventricular contraction  
 (d) Beginning of the systole

20. Blood pressure in the pulmonary artery is [NEET (Phase - I) 2016]  
 (a) Same as that in the aorta  
 (b) More than that in the carotid  
 (c) More than that in the pulmonary vein  
 (d) Less than that in the venae cavae
21. A decrease in blood pressure/volume will not cause the release of [NEET 2017]  
 (a) Renin (b) Atrial natriuretic Factor  
 (c) Aldosterone (d) ADH

### Lymphatic system

1. Lymph (nodes) glands form [MP PMT 1999]  
 (a) Hormones (b) Lymphs  
 (c) Antigens (d) Antibodies
2. Which of the following is first to receive lymphatic duct from legs [GUJCET 2007]  
 (a) Left subclavian vein (b) Right subclavian vein  
 (c) Right lymphatic duct (d) Thoracic lymphatic duct
3. Lymph is colourless because [MP PMT 1999]  
 (a) WBC are absent (b) WBC are present  
 (c) Haemoglobin is absent (d) RBC are absent
4. Which organ is considered as "Graveyard of RBC" where most of them are destroyed by macrophages [NCERT; AFMC 2001; AMU (Med.) 2006; CBSE PMT (Mains) 2012]  
 Or  
 Which of the following organs can be called as a sort of "blood bank"  
 (a) Red bone marrow (b) Spleen  
 (c) Kidney (d) Intestine
5. Which of the following is not a major organ of lymphatic system [MP PMT 2010; AFMC 2012]  
 (a) Lymph nodes (b) Thymus  
 (c) Kidney (d) Spleen
6. An antibody is a [MP PMT 1996; BVP 2003]  
 (a) Molecule that specifically inactivates an antigen  
 (b) WBC which invades bacteria  
 (c) Secretion of mammalian RBC  
 (d) Component of blood
7. Antigens are present [CBSE PMT 1995]  
 (a) Inside nucleus (b) On cell surface  
 (c) Inside cytoplasm (d) On nuclear membrane
8. Function of human spleen is to  
 (a) Control the pulse rate (b) Secrete hormone  
 (c) Stimulate heart (d) Control blood volume
9. T-Lymphocytes originate from [MP PMT 2001; WB JEE 2009]  
 (a) Thymus (b) Bone marrow  
 (c) Liver (d) None of these
10. Lymphoid tissue is found in [CPMT 2000; BHU 2006]  
 (a) Thymus (b) Tonsils  
 (c) Lymph nodes (d) All of these
11. If the spleen is removed from the body of an adult man then  
 (a) Antibody production will be less  
 (b) RBC production will be lowered  
 (c) WBC production will be lowered  
 (d) Filtration of dead RBC will stop

12. Red pulp and white pulp are found in [CBSE PMT 1991]  
 (a) Bone (b) Spleen  
 (c) Tooth (d) Skeletal Muscle
13. Spleen is [CBSE PMT 2001; BVP 2001]  
 (a) Haemopoietic (b) Lymphoid  
 (c) Reproductive (d) Celluloid
14. The principle function of the lymph node in the man is  
 (a) Destruction of old RBC  
 (b) Destruction of old WBC  
 (c) Collection and destruction of pathogens in the blood  
 (d) Production of WBC
15. The lymph serves to [CBSE PMT 1995; BHU 2004]  
 (a) Transport  $O_2$  to the brain  
 (b) Transport  $CO_2$  to the lungs  
 (c) Return the interstitial fluid to the blood  
 (d) Return the WBCs and the RBCs to the lymph nodes
16. Humoral antibodies are produced by  
 (a) B-cells (b) T-cells  
 (c) Globulins (d) Plasma cells
17. If thymus gland of an infant is removed which of the following will not form [CPMT 1993]  
 (a) T-lymphocytes (b)  $\beta$ -lymphocytes  
 (c) Erythrocytes (d) Granulocytes
18. Which vertebrate organ receives only oxygenated blood [KCET 2001]  
 (a) Gill (b) Lung  
 (c) Spleen (d) Liver
19. Lymph vessels are united to form [BHU 2001]  
 (a) Lymph heart (b) Cisterna chyli  
 (c) Thoracic duct (d) Jugular vein
20. Immunoglobulins are produced by [CBSE PMT 1996]  
 (a) Lymphocytes (b) Spleen  
 (c) Leucocytes (d) Monocytes

### Portal system

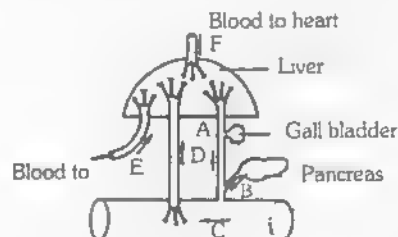
1. A portal system is a system in which  
 (a) A vein starts from an organ and ends up in heart  
 (b) An artery breaks up in an organ and restarts by the union of its capillaries  
 (c) The blood from the gut is brought into the kidney before it is poured into posterior venacava  
 (d) A vein breaks up in an organ into capillaries and restarts by their union as a new vein in the same organ
2. A vein that collects blood from one network of capillaries and transports it directly to a second capillary network in another region of the body, without returning to the heart is called [Odisha JEE 2010; WB JEE 2012]  
 (a) Coronary vein (b) Pulmonary vein  
 (c) Portal vein (d) Carotid vein
3. Hepatic portal system starts from [NCERT]  
 (a) Digestive system to liver (b) Kidney to liver  
 (c) Liver to heart (d) Liver to kidney
4. Which of the following vessel in rabbit starts with capillaries and ends in capillaries [RPMT 2002]

Or

Which one of the following vein breaks up into capillaries [MP PMT 1992]

- (a) Pulmonary artery (b) Renal vein  
 (c) Hepatic portal vein (d) Renal artery

5. Blood circulation that starts in capillaries and ends in capillaries is called [NCERT; J & K CET 2010]  
 (a) Portal circulation (b) Hepatic circulation  
 (c) Cardiac circulation (d) None
6. The diagram below shows how things get to and from the liver. They are labelled as A, B, C, D, E and F. Which one of the following labellings is the correct one [Kerala PMT 2004]



- (a) A is the hepatic portal vein and E is the hepatic vein  
 (b) C is the intestine and F is the hepatic portal vein  
 (c) D is the hepatic portal vein and F is the hepatic vein  
 (d) B is pancreatic artery and E is the hepatic artery  
 (e) D is the hepatic portal vein and E is the hepatic vein
7. Which of the following carries glucose from digestive tract to liver [CBSE PMT 1999; BHU 2001]  
 (a) Hepatic artery (b) Hepatic portal vein  
 (c) Pulmonary vein (d) None of these
8. The renal portal system is made of [Pune CET 1998]  
 (a) Femoral, renal portal veins  
 (b) Sciatic, renal portal veins  
 (c) Renal portal veins  
 (d) Femoral, sciatic, renal portal veins
9. The hepatic portal vein drains blood to liver from [NEET 2017]  
 (a) Heart (b) Stomach  
 (c) Kidneys (d) Intestine

Q

NCERT

Exemplar Questions

1. Mark, among the following a cell which does not exhibit phagocytotic activity [NCERT]  
 (a) Monocytes (b) Neutrophil  
 (c) Basophil (d) Macrophage
2. One of the common symptoms observed in people infected with Dengue fever is [NCERT]  
 (a) Significant decrease in RBC count  
 (b) Significant decrease in WBC count  
 (c) Significant decrease in platelets count  
 (d) Significant increase in platelets count
3. Which among the followings is correct during each cardiac cycle [NCERT]  
 (a) The volume of blood pumped out by the Rt and Lt ventricles is same  
 (b) The volume of blood pumped out by the Rt and Lt ventricles is different  
 (c) The volume of blood received by each atrium is different  
 (d) The volume of blood received by the aorta and pulmonary artery is different

4. Cardiac activity could be moderated by the autonomous neural system. Tick the correct answer [NCERT]  
 (a) The parasympathetic system stimulates heart rate and stroke volume  
 (b) The sympathetic system stimulates heart rate and stroke volume  
 (c) The parasympathetic system decreases the heart rate but increase stroke volume  
 (d) The sympathetic system decreases the heart rate but increase stroke volume
5. Mark the pair of substances among the following which is essential for coagulation of blood [NCERT]  
 (a) Heparin and calcium ions  
 (b) Calcium ions and platelet factors  
 (c) Oxalates and citrates  
 (d) Platelet factors and heparin
6. ECG depicts the depolarization and repolarisation processes during the cardiac cycle. In the ECG of a normal healthy individual one of the following waves is not represented [NCERT]  
 (a) Depolarisation of atria (b) Repolarisation of atria  
 (c) Depolarisation of ventricles (d) Repolarisation of ventricles
7. The cells involved in inflammatory reactions are [NCERT]  
 (a) Basophils (b) Neutrophils  
 (c) Eosinophils (d) Lymphocytes
8. The second heart sound (dubb) is associated with the closure of [NCERT]  
 (a) Tricuspid valve  
 (b) Semilunar valves  
 (c) Bicuspid valve  
 (d) Tricuspid and bicuspid valves
9. Which of the following correctly explains a phase/event in cardiac cycle in a standard electrocardiogram [NCERT]  
 (a) QRS complex indicates atrial contraction  
 (b) QRS complex indicates ventricular contraction  
 (c) Time between S and T represents atrial systole  
 (d) P-wave indicates beginning of ventricular contraction
10. Which of the following statements is incorrect [NCERT]  
 (a) A person of 'O' blood group has anti 'A' and anti 'B' antibodies in his blood plasma  
 (b) A person of 'B' blood group can't donate blood to a person of 'A' blood group  
 (c) Blood group is designated on the basis of the presence of antibodies in the blood plasma  
 (d) A person of AB blood group is universal recipient
11. What would be the cardiac output of a person having 72 heart beats per minute and a stroke volume of 50 ml [NCERT]  
 (a) 360 mL (b) 3600 mL  
 (c) 7200 mL (d) 5000 mL
12. Match the terms given under Column 'A' with their functions given under Column 'B' and select the answer from the options given below

Column 'A'	Column 'B'
A. Lymphatic system	i. Carries oxygenated blood
B. Pulmonary vein	ii. Immune Response
C. Thrombocytes	iii. To drain back the tissue fluid to the circulatory system
D. Lymphocytes	iv. Coagulation of blood

Options [NCERT]  
 (a) A-ii, B-i, C-iii, D-iv (b) A-iii, B-i, C-iv, D-ii  
 (c) A-iii, B-i, C-ii, D-iv (d) A-ii, B-i, C-iii, D-iv

13. Read the following statements and choose the correct option [NCERT]  
 Statement 1 : Atria receive blood from all parts of the body which subsequently flows to ventricles.  
 Statement 2 : Action potential generated at sino-atrial node passes from atria to ventricles.  
 (a) Action mentioned in Statement 1 is dependent on action mentioned in Statement 2  
 (b) Action mentioned in Statement 2 is dependent on action mentioned in Statement 1  
 (c) Action mentioned in Statements 1 and 2 are independent of each other  
 (d) Action mentioned in Statements 1 and 2 are synchronous



## Critical Thinking

### Objective Questions

1. Blood of *Periplaneta* does not carry oxygen because [RPMT 2001]  
 (a)  $O_2$  is transported by respiratory tubules  
 (b) Its respiration is anaerobic  
 (c) There is no cells in its blood  
 (d) *Periplaneta* does not has any blood vessel
2. A vein differs from the artery in having [CBSE PMT 1993; MP PMT 1993, 94; Pb. PMT 2000]  
 (a) Narrow lumen  
 (b) Strong cuticular and muscular wall  
 (c) Valves to control direction of flow  
 (d) Dark pigmented wall
3. Which of the following diagram of cardiac cycle is possible in case of human heart, if the shaded and nonshaded sectors represents different events (systole or diastole) [NCERT]
- (a)

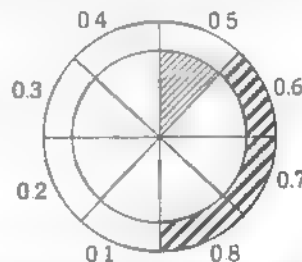
(b)

(c)

(d)
4. pH of blood in artery and vein is  
 (a) Same  
 (b) More in artery and less in vein  
 (c) More in vein and less in artery  
 (d) Not definite
5. Largest blood vessel in body is [MP PMT 1993; MHCET 2000]  
 (a) Carotid artery (b) Dorsal aorta  
 (c) Phrenic artery (d) Coronary artery
6. All arteries carry oxygenated blood except [MP PMT 2001; AFMC 2003]  
 (a) Systemic (b) Hepatic  
 (c) Pulmonary (d) Cardiac

7. Choose the correct proportion with respect to the distribution of blood in the body of man. [Kerala PMT 2004]
- 5% to heart muscles, 15% to brain, 25% to liver, 25% kidney, 15% to bones, 15% to other organs
  - 20% to heart muscles, 10% to brain, 10% to liver, 25% to kidney, 10% to bones, 25% to other organs
  - 10% to heart muscles, 10% to brain, 10% to liver, 40% to kidney, 15% to bones, 15% to other organs
  - 5% to heart muscles, 20% to brain, 20% to liver, 15% to kidney, 5% to bones, 35% to other organs
  - 1% to heart muscles, 20% to brain, 30% to liver, 40% to kidney, 5% to bones, 40% to other organs
8. Given below are four statements (A-D) regarding human blood circulatory system
- Arteries are thick-walled and have narrow lumen as compared to veins
  - Angina is acute chest pain when the blood circulation to the brain is reduced
  - Persons with blood group AB can donate blood to any person with any blood group under ABO system
  - Calcium ions play a very important role in blood clotting
- Which two of the above statements are correct [NCERT; CBSE PMT (Malna) 2010]
- (A) and (D)
  - (A) and (B)
  - (B) and (C)
  - (C) and (D)
9. Heaviness with severe chest pain which may disappear with rest indicates [MHCET 2015]
- Angina pectoris
  - Atherosclerosis
  - Arteriosclerosis
  - Hyperthyroidism
10. In haemoglobin iron is present in [CBSE PMT 1992]
- Ferrous form
  - Ferric form
  - Metallic form
  - Any form
11. Mixing up of arterial and venous blood does not take place in a heart having [AIIMS 1992]
- Two chambers
  - Four chambers
  - Three chambers
  - None of the above
12. When the right ventricle contracts the blood goes into [CBSE PMT 1992]
- Aorta
  - Brain
  - Pulmonary artery
  - None
13. Trilobed valve present between right atrium and ventricle in mammalian heart is [NCERT; CBSE PMT 1993; AFMC 2008; Kerala PMT 2008]
- Triac
  - Triad
  - Tricuspid or besian
  - Tngeminal
14. Stimulation of the vagus nerve will make the heart beat
- Faster
  - 70 times/minute
  - Slower
  - Normal
15. The rate of heart beat per minute is highest in case of
- Elephant
  - Whale
  - Man
  - Mouse
16. Which one of the following animals has two separate circulatory pathways [AIPMT 2015]
- Lizard
  - Whale
  - Shark
  - Frog

17. Which one represents pulmonary circulation [NCERT; Kerala PMT 2002]
- In aunde (oxygenated blood) – lungs (deoxygenated blood) – Right auricle
  - Left auricle (deoxygenated blood) – lungs (oxygenated blood) – Right auricle
  - Left auricle (oxygenated blood) – lungs (deoxygenated blood) – Left auricle
  - Right auricle (deoxygenated blood) – lungs (oxygenated blood) – Left auricle
18. Mammals have biconcave RBC. The physiological use for it is [NCERT]
- To decrease the surface area
  - To increase the surface area
  - To be packed like coins
  - None of the above
19. Systole refers to the contraction of [BHU 2002]
- SA node
  - AV node
  - Major arteries
  - Atria and ventricles
20. Which set is correct [CBSE PMT 2001]
- Sebum – Analgesic
  - Vitamin – Nicotine
  - Corpuscallosum – Graffian follicle
  - Bundle of His – Purkunje fibre
21. In rabbit, function of spleen is [CPMT 1995]
- Blood purification
  - Respiration
  - Excretion
  - None of the above
22. See the following Cardiac Cycle. For how much duration does joint systole occur in the given cardiac cycle [NCERT]
- 0.4 seconds
  - 0.7 seconds
  - 0.3 seconds
  - None



## R Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

- If both the assertion and the reason are true and the reason is a correct explanation of the assertion
  - If both the assertion and reason are true but the reason is not a correct explanation of the assertion
  - If the assertion is true but the reason is false
  - If both the assertion and reason are false
  - If the assertion is false but reason is true
1. Assertion : Heart valves resemble swing doors in action.  
Reason : Valves are present in the heart chamber, at the opening of the heart into large arteries and veins.
2. Assertion : WBCs accumulate at the site of wounds by diapedesis.  
Reason : It is the squeezing of leucocytes from the endothelium. [AIIMS 2002]

3. Assertion : Saline water is not given to patients of hypertension.  
Reason : Saline water can cause vomiting and may drop blood pressure suddenly causing cardiac arrest. [AIIMS 2000]
4. Assertion : EEG is of immense diagnostic value in the cardiac diseases.  
Reason : Defects in cardiac functions can be reflected in changes in the pattern of electrical potentials recorded in the EEG.
5. Assertion : An artificial pacemaker can replace the sinoatrial node of heart.  
Reason : This is because, an artificial pacemaker is capable of stimulating the heart electrically to maintain its beats
6. Assertion : Electrocardiogram is record of electrical activity of the heart which shows certain waves called P, Q, R, S and T waves.  
Reason : It gives important information concerning the spread of excitation to the different parts of heart and it is of value in the diagnosis of cases of abnormal cardiac rhythm and myocardial damage. [AIIMS 2000]
7. Assertion : Blood pressure is arterial blood pressure.  
Reason : It is measured by sphygmomanometer. [AIIMS 2000]
8. Assertion : Heart of fish contains only deoxygenated blood.  
Reason : Oxygenated blood do not return back to the heart in fishes.
9. Assertion : Blood flows at a very slow velocity in the lacunae and sinuses of prawn.  
Reason : This happens because of the absence of heart in the prawn.
10. Assertion : The muscle fibres of SA node possess the lowest rhythmicity among all cardiac muscle fibres.  
Reason : Due to this fact, it can initiate excitatory waves at the highest rate [AIIMS 1997]

## Answers

### Structure and function of heart

1	c	2	c	3	a	4	b	5	a
6	a	7	b	8	c	9	a	10	d
11	d	12	b	13	a	14	a	15	b
16	d	17	a	18	a	19	b	20	a
21	a	22	a	23	a	24	d	25	a
26	a	27	c	28	d	29	a	30	b
31	d	32	d	33	c	34	b	35	a
36	b	37	b	38	a	39	b	40	d
41	c	42	b	43	c	44	a	45	c
46	d	47	c	48	b	49	a	50	b

51	a	52	d	53	d	54	d	55	c
56	b	57	d	58	a	59	c	60	a
61	c	62	d	63	a	64	b	65	c
66	d	67	d	68	a	69	a	70	c
71	a	72	c	73	a	74	c	75	b
76	c	77	c	78	a	79	d	80	a
81	c	82	b	83	a	84	d	85	b
86	b	87	a	88	b	89	a	90	a
91	b	92	d	93	c	94	d	95	a
96	b								

### Blood vessel

1	a	2	d	3	a	4	a	5	b
6	b	7	b	8	a	9	b	10	d
11	c	12	c	13	d	14	c	15	b
16	d	17	a						

### Blood pressure, ECG

1	d	2	c	3	a	4	b	5	a
6	d	7	c	8	d	9	b	10	a
11	c	12	d	13	a	14	c	15	c
16	a	17	d	18	c	19	b	20	c
21	b								

### Lymphatic system

1	d	2	d	3	c	4	b	5	c
6	a	7	b	8	d	9	b	10	d
11	d	12	b	13	b	14	c	15	c
16	a	17	a	18	c	19	c	20	a

### Portal system

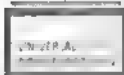
1	d	2	c	3	a	4	c	5	a
6	c	7	b	8	d	9	d		

### NCERT Exemplar Questions

1	c	2	c	3	a	4	b	5	b
6	b	7	a	8	b	9	b	10	c
11	b	12	b	13	b				

### Critical Thinking Questions

1	a	2	c	3	b	4	b	5	b
6	c	7	d	8	a	9	b	10	a
11	b	12	c	13	c	14	c	15	d
16	b	17	d	18	b	19	d	20	d
21	a	22	a						


**Assertion and Reason**

1	b	2	b	3	c	4	d	5	a
6	a	7	b	8	a	9	c	10	e

# **Answers and Solutions**

**Structure and function of heart**

5. (a) Lubb is the first, low pitched heart sound produced due to the closure of bicuspid and tricuspid valves at the start of ventricular systole.
6. (a) The bicuspid valve is a valve consisting of two membranous flap or cups situated between the atrium and ventricle of the left side of the heart in mammals.
10. (d) The heart of cockroach is pulsatile and formed of 13 inverted funnel-shaped segmental chamber, each chamber (except last one) has a pair of apertures called ostia which open into the pericardial sinus.
16. (d) The amount of blood flowing from the heart over a given period of time is known as the cardiac output. It depends upon the heart rate and stroke volume.  
Cardiac output = stroke volume  $\times$  heart rate
17. (a) The left atrium receives oxygenated blood from the lungs through four of pulmonary veins.
18. (a) Within the lateral walls of ventricles and help in conduction of cardiac impulse.
21. (a) Pericardium (Protective covering) and pericardial fluid protects the heart from shocks, mechanical injuries and keeps it moist and also allows free movements of the heart.
22. (a) The chordae tendineae or heart strings are cord like tendons that connect the papillary muscles to the tricuspid valve and the mitral valve in the heart. The chordae tendinae prevents the flaps from being everted upto the right atrium, these cord like tendons hold in position other flaps such as bicuspid or mitral valve.
27. (c) First sound is 'lubb' a long and booming sound (related by the closure of tricuspid valve and second sound is 'dupp' a short and due to closure of semi lunar valves.
29. (a) Pace maker (SA node) which lies in the wall of the right atrium near the opening of the superior vena cava.
35. (e) Open circulatory system occurs in invertebrate animals such as arthropods (e.g. insects, spiders, crabs and lobsters) and some molluscs (e.g. snails, oysters and clams)
42. (b) Sinus venosus is the first chamber of the heart in fish, amphibia and reptiles. In fish it receives blood from the cuvenan ducts and hepatic veins and leads into the single auricle. In amphibians and reptiles it receives blood from the three venae cavae and leads to the right auricle. Birds and mammals have no sinus venosus.
45. (c) 'Bundle of His' is a part of conducting system of human heart.
46. (d) The AV-valves close due to sharp rise of intraventricular pressure, their closure produces first heart sound LUBB.
47. (c) When irregularity in the heart rhythm occurs, normal heart rhythm can be restored and maintained by surgically implanting an artificial pace maker, a device that sends out small electrical current to stimulate the heart to contract.
52. (d) Spiral valve is a valve present in truncus arteriosus of amphibian heart guiding flow of different type of blood in three aortic arches.
56. (b) Pleura is a membrane in which the lungs of a vertebrate are suspended from the wall of the thorax i.e., it is the covering of the lungs.
57. (d) AV-node delays the impulse of contraction before transmitting it to the ventricles. Thus sets the time interval between the contraction of auricles and ventricles.
59. (c) Cardiac output = stroke volume  $\times$  ventricular systole/minute  
= 70 ml  $\times$  72 (min) = 5040 ml/min  
= about 5.5 litres.
60. (a) Alary muscles are a pair of triangular fan like muscles in the floor of pericardial sinus of cockroach. The respiratory movements of abdomen and contraction of alary muscles increase the pumping force of the cockroach's heart
62. (d) The wall of ventricles are thicker than those of auricles. Thickest wall is found in the left ventricle.
66. (d) The wall of heart has three layer : epicardium, myocardium and endocardium.
68. (a) Cardiac impulse (Heart beat) normally originate from the pace maker (S.A. node).
69. (a) In earthworm, an annelid, 4 pairs of thick, muscular, pulsatile hearts are present
70. (c) Capillary has no muscular wall. Its wall is made of a single layer of endothelial cell
75. (b) Inferior vena cava (post caval) collect blood from lower part of trunk and hind limbs.
76. (c) Superior vena cava (pre caval) collect blood from head, fore limbs and upper part of chest.
80. (a) In the right atrium adjoining the internal septum, an oval depression the fossa ovalis.
81. (c) Bundle of His is a network of muscle fibres found in between two ventricles.
82. (b) Veins bring blood from the body to the heart.
84. (d) Right auricle receives deoxygenated blood from the body via sinus venosus in the lower vertebrates.
86. (b) Atherosclerosis is narrowing of arteries and arterioles due to deposition of fats on their lining
87. (a) During auricular systole, the auricles contract and drain most of their blood into the respective ventricles.
89. (a) Transmission of impulse occurs  
S-A node  $\rightarrow$  A-V node  $\rightarrow$  Bundle of His  $\rightarrow$  Purkinje system.
91. (b) Since the impulse originates in the heart it self by a patch of modified heart muscle without requiring any external stimulation
92. (d) Thoracic duct is a dorsal longitudinal lymphatic vessel which begins below diaphragm, ascends in front of vertebral column and drains into innominate vein at the base of neck
96. (b) In the given diagram 'D' represent the vena cava. Vena cava is either of the two large veins that carry deoxygenated blood into the right atrium.

### Blood vessel

2. (d) Because serotonin is a vaso-constrictor.
4. (a) Pulse can be detected in superficial artery like radial artery of wrist and temporal artery.
7. (b) A pair of phrenic arteries arise from the aorta and supply the diaphragm. Phrenic artery present in human but absent in frog.
9. (b) Blocking of arteries due to deposition of fat and calcium is called Atherosclerosis. Emphysema is a chronic obstructive lung disease
10. (d) In the region behind 13<sup>th</sup> segment, blood laden with digested nutrients and  $O_2$  is collected in the dorsal vessel while in anterior region of body, some of this blood is supplied by dorsal vessel to various parts.
11. (c) Arteries are best defined as vessels which carry blood away from the heart to different organs.
12. (c) Intravenous injection is given for rapid distribution of drugs/substance. Intramuscular injection is given for producing local effect
13. (d) Least concentration of urea is found in renal vein. This is because urea is excreted through urine formed in kidney.

### Blood pressure, ECG

2. (c) Blood pressure is measured in mm of mercury by an instrument known as sphygmomanometer. The instrument was invented by an Italian Doctor Riva-Rocci in 1896
4. (b) ECG is the record of changes in electrical potential of heart during one beat.
5. (a) It is also called ventricular complex.
9. (b) Upon systole of left ventricle blood is pushed in aorta, which creates systolic blood pressure which is 120 mm Hg.
12. (d) With the increase in intra cranial pressure, the cerebral blood flow is reduced. This increased pressure also stimulates the vasomotor centre and increases systemic blood pressure
13. (a) Hypertension occurs if the blood pressure is 190/110. This can harm the vital organ like brain and kidneys.
15. (c) Systole is the muscular contraction of the heart or of any chamber of it. Commonly, it is used to refer to the ventricles of human heart. During this stage the openings for CSA and PT are open, so the blood leaves the ventricles.
16. (a) Blood is diverted towards alimentary canal. Therefore the pressure of blood falls in brain.
21. (b) Except ANF which is released by Wall of atrium, rest three increase blood pressure and GFR by various methods. ANF will further decrease blood pressure

### Lymphatic system

2. (d) Essentially all the lymph from the lower part of the body even most of that from the legs flows up the thoracic duct and empties into the venous system at the juncture of left internal jugular vein and subclavian vein.

3. (c) Colour of blood is due to presence of haemoglobin in RBCs since RBCs are absent in lymph so lymph is colourless.
4. (b) Old RBCs are destroyed along with pathogens by phagocytosis carried out by macrophages. Thus, spleen acts as graveyard of RBCs.
6. (a) An antibody is a molecule that specifically inactivates an antigen.
7. (b) Antigen are present on cell surface and cause the formation of antibodies specifically reacting with them.
8. (d) So spleen is also called the blood reservoir of human body.
9. (b) Haemopoietic stem cells differentiate into T-and B-lymphocytes in the bone marrow T- cells then migrate to thymus gland for their proliferation.
16. (a) Humoral or Antibody mediated immune system is formed or proteinous defensive chemicals called antibodies which are produce by B lymphocyte and circulate in the plasma of blood and lymph and protect the body from bacteria and virus.
17. (a) Surgical removal of thymus gland of new born shall result in the failure to produce T lymphocytes.
19. (c) Lymphatic vessels unite to form two main vessels called thoracic duct and right lymphatic duct

### Portal system

3. (a) Hepatic portal system starts from digestive system and finishes in liver.
4. (c) Hepatic portal vein in Rabbit starts with capillaries and ends in capillaries.
5. (a) Blood circulation that starts in capillaries and ends in capillaries is called portal circulation.
7. (b) Hepatic portal vein carries blood rich in absorbed food material such as glucose and amino acid from intestine to liver.
8. (d) Renal portal system is found in frog in which femoral, sciatic and renal portal veins are include

### Critical Thinking Questions

1. (a) Blood of cockroach lacks respiratory pigment. Hence,  $O_2$  is carried by the respiratory tubules.
2. (c) Vein contain valves to prevent back flow of blood.
4. (b) Because in vein presence of  $CO_2$  decreases the pH.
5. (b) Largest blood vessel in the body is carotid systemic or dorsal aorta, It is a question marked shaped long vessel, that arise from left ventricle of the heart.
8. (a) Angina is due to reduced blood supply to heart wall. Person with blood group AB is universal recipient.
10. (a) In haemoglobin iron is present in ferrous ( $Fe^{++}$ ) state.
12. (c) During ventricular systole. The pressure increases in the ventricles, thus forcing the oxygenated blood from left ventricle into systemic aorta and deoxygenated blood from right ventricle into pulmonary aorta.
14. (c) Stimulation of vagus nerve decreases the heart rate but its continuous stimulation shows no further decrease.

15. (d) Under the normal conditions heart rate has an inverse relation with the size of the animal.
  16. (b) Whale is a mammal and has 4 chambered heart with 2 atria and 2 ventricles, oxygenated and deoxygenated blood flow on separate sides.
  17. (d) Because pace maker of the heart is capable of initiating and regulating the heart beat.
  18. (b) To allow relatively quick saturation and dissaturation with  $O_2$  and  $CO_2$ .
  19. (d) Systole refers to contraction of atria (atrial systole) which propels blood into ventricles and contraction of ventricles (ventricular systole) expels blood into aorta and pulmonary artery.
  21. (a) Macrophages of spleen engulf and destroy wornout blood corpuscles, dead and live pathogens, cell Lebris, Pigment gramules and other useless particulate materials, thus regularly cleaning the blood of its impurities.
5. (a) An artificial pacemaker is a therapeutic instrument which is implanted in the heart of patients to generate the heart beat. A pacemaker is used when the normal heart rate of 72-80 drops down to abnormally low levels like 30-40 due to diseases or operations and threatens the life of the patient. Sometime, the SA node may become damaged or defective. It then fails to generate cardiac impulses at the normal rate. The heart beats become abnormally slow and irregular, and ventricles fail to pump the required amount of blood. This is remedied by the surgical grafting of artificial pacemaker instrument in the chest of the patient. The artificial pacemaker stimulates the heart electrically at regular intervals to maintain its beats. Thus it replaces the SA node as the originator of the cardiac impulse.

### Assertion and reason

1. (b) The valves present in heart when pushed by blood in the right direction, the flaps of the valve swing apart and allow the blood to flow through, but when pushed in the opposite direction, the flaps close sharply to block the passage through the valve. Thus these valves resemble swing doors in action. Hence the valves of the heart maintain unidirectional flow of blood and prevent it's regurgitation in the opposite direction.
  2. (b) During the wound, germs are removed by the process of phagocytosis by WBC. WBCs accumulate at the site of wound by diapedesis. It is the squeezing of leucocytes out from the endothelium of capillaries to fight against foreign agent.
  3. (c) Saline water is not given to a patient of hypertension because it may cause rise in blood pressure which may be fatal to patient.
  4. (d) As the cardiac impulse spreads over the cardiac chambers and causes their contractions, electrical changes sweep over the cardiac chambers in a specific sequence. These changes in the electrical potential over the heart can be recorded by fixing leads on two arms, the left leg and the chest, and connecting them to an apparatus called electrocardiograph. The record is called electrocardiogram (ECG). An electrocardiogram is the recording of the various events of the cardiac cycle. Defects in cardiac functions or structures are reflected in changes in the pattern of electrical potentials recorded in the ECG. The ECG is, therefore of immense diagnostic value in cardiac diseases. On the other hand, EEG is an index of the brain functions. EEG or electroencephalogram represents the spontaneous electrical activity of the brain as recorded from the electrodes placed on the scalp. EEG wave pattern obtained shows certain characteristic features of the brain like the frequency amplitude of the signals of brain. Thus any deviation from the normal caused either by brain disease or change in the physiological state of the brain can be easily detected by EEG.
6. (a) ECG consists of P-wave, QRS wave and T-wave. ECG gives important information concerning the spread of excitation to the different parts of heart and in the diagnosis of abnormal cardiac rhythm and myocardial damage.
  7. (b) Blood pressure is the arterial blood pressure taken in left brachial artery and the instrument used to measure blood pressure is sphygmomanometer.
  8. (a) The heart is a pumping organ for blood circulation which consists of chambers communicating with each other. In fishes the heart is two-chambered, consisting of an auricle and a ventricle. An accessory chamber called sinus venosus is also present which serves as a reservoir and opens anteriorly into auricle through the sino - atrial aperture. Fish heart contains and pumps only deoxygenated blood because after getting oxygenated from gills, the blood doesn't return back to the heart. Instead, it is supplied directly to the various parts of the body
  9. (c) Lacunae and sinuses are the open spaces and channels present in the tissues of prawn. Prawn possesses a heart which pumps the oxygenated blood into some arteries. These arteries directly open into the lacunae and sinuses. The tissues are thus in direct contact with blood. A sufficiently high blood pressure, however, cannot be maintained in the open lacunae and sinuses inspite of the pumping action of the heart. So, blood flows at a very slow velocity in the lacunae and sinuses.
  10. (e) SA node and AV node are the contraction node. SA node possess the highest rhythmicity among all cardiac muscle fibres and can initiate excitory wave at highest rate.

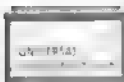


## Body Fluids and Circulation

## Self Evaluation Test

- Lack of pulmonary surfactant produces [AMU (Med.) 2009]
    - Asthma
    - Emphysema
    - Cystic fibrosis
    - Respiratory distress syndrome
  - Myogenic heart is found in [MH CET 2000]
    - Man
    - Fishes
    - Earthworm
    - Cockroach
  - If blood cells are eliminated from the blood, the liquid left is [MP PMT 1993, 98]
    - Serum
    - Plasma
    - Lymph
    - Synovial fluid
  - The heart beat increases at the time of interview due to [NCERT; AIIMS 1999; BHU 2012]
    - Corticotrophic hormone
    - Hyper secretion of renin
    - Secretion of adrenaline
    - Antidiuretic hormone secretion
  - Blood vessels that contain valves are called [CBSE PMT 1993]
    - Arteries
    - Veins
    - Capillaries
    - All the above
  - Match the blood vessels of human heart listed under Column-I with the functions given under Column-II. Choose the answer which gives the correct combination of the alphabets of the two columns
 

Column-I (Blood vessel)		Column-II (Function)	
A.	Superior vena cava	p.	Carries deoxygenated blood to lungs
B.	Inferior vena cava	q.	Carries oxygenated blood to lungs
C.	Pulmonary artery	r.	Brings deoxygenated blood from lower parts of the body to the right atrium
D.	Pulmonary vein	s.	Brings oxygenated blood to the left atrium
		t.	Brings deoxygenated blood from upper parts of the body into the right atrium
- [NCERT; KCET 1999; AIIMS 2009]
- A = t, B = p, C = r, D = q
  - A = t, B = r, C = p, D = s
  - A = s, B = t, C = r, D = p
  - A = t, B = p, C = q, D = r
- Valves are found in veins to check the backflow of blood flowing under
    - Low pressure
    - High pressure
    - No pressure
    - Very high pressure
  - A four chambered heart is not found in [KCET 2004]
    - Mammals
    - Birds
    - Snake
    - Crocodile
  - To which organ does femoral artery supply blood [Odisha JEE 2005]
    - Dorsal part of thigh
    - All parts of hind limb
    - Ventral part of hind limb
    - Rectum
  - Blood returns from lungs to heart through
    - Right auricle
    - Right ventricle
    - Left ventricle
    - Left auricle
  - Although much  $\text{CO}_2$  is carried in the blood, yet blood does not becomes acidic. This is because [CBSE PMT 1995]
    - In  $\text{CO}_2$  transport, blood buffers play an important role
    - $\text{CO}_2$  combines with water to form  $\text{H}_2\text{CO}_3$  which is neutralised by  $\text{H}_2\text{CO}_3$
    - $\text{CO}_2$  is continuously diffused through the tissues and is not allowed to accumulate
    - $\text{CO}_2$  is absorbed by leucocytes
  - Chordae tendinae are found in [NCERT; CBSE PMT 1993; Kerala PMT 2010; MP PMT 2013]
    - Ventricle of heart
    - Atria of heart
    - Joints
    - Ventricle of brain
  - Arteries are [CPMT 1996; DPMT 2006]
    - Thin-walled and blood flows under diminished pressure
    - Thick-walled and blood flows under high pressure
    - Thin-walled and blood flows under high pressure
    - Thick-walled and blood flows under diminished pressure
  - Which one of the following doctors performed the first heart transplant
    - Hargovind Khurana
    - Christian Barnard
    - Watson
    - William Harvey
  - Innominate is
    - A nerve and artery
    - A muscle and artery
    - Skeleton part and artery
    - A nerve and vein
  - Neurogenic heart is characteristic of [CBSE PMT 1995; MP PMT 2013]
    - Lower vertebrates
    - Humans
    - Rat
    - Rabbit
  - Bicuspid valve is also called as [BCECE 1995; MP PMT 2004]
    - Mitral valve
    - Eustachian valve
    - Pulmonary valve
    - Ventricular valve
    - None of the above



18. An adult human with average health has systolic and diastolic pressures as [NCERT; CBSE PMT 1998; MH CET 2000; KCET 2000, 01; BVP 2002; HPMT 2005; WB JEE 2009]
- 80 mm Hg and 88 mm Hg
  - 70 mm Hg and 120 mm Hg
  - 120 mm Hg and 80 mm Hg
  - 50 mm Hg and 80 mm Hg
19. Papillary muscles are found in mammalian [MP PMT 2009]
- Auricles
  - Ventricles
  - Pinna
  - Eyes

## Answers and Solutions

1	b	2	a	3	b	4	c	5	b
6	b	7	a	8	c	9	a	10	d
11	a	12	a	13	b	14	b	15	c
16	a	17	a	18	c	19	b		

2. (a) Myogenic heart is found in molluscs and vertebrates.
3. (b) The blood is composed of a faintly yellow transparent fluid known as the plasma and floating in this fluid are numerous cells or corpuscles of different kinds. Thus  
Blood - Blood cells = Plasma.

4. (c) Adrenaline increases the heart beat normally during active and stress conditions.
8. (c) Four chambered heart is found only in mammals and birds except some reptiles such as crocodiles, gavialis and alligators.
9. (a) The general distribution of the femoral arteries is to the lower abdominal wall, groin, external genitals and muscles of the dorsal part of the thigh
11. (a) Its due to buffer action of blood.
12. (a) Chordae tendinae are numerous, strong inelastic thread like tendons present in the ventricles of the mammalian heart.
13. (b) Arteries are thick walled, carrying oxygenated blood from heart to various parts of body at high pressure.
14. (b) The first human heart transplant was performed on 3rd December, 1967 by a team of 30 doctors headed by Prof. Christian Barnard on 55 years old Louis Washkansky at the Groote Schuur Hospital, Cape Town, South Africa. In spite of the operation by a leading surgeon Washkansky died on 21st December, 1967.
16. (a) Neurogenic heart stops beating on cutting nerve supply.
17. (a) The bicuspid valve between the left atrium and the left ventricle of mammalian heart is known as mitral valve.
18. (c) In a normal human being, the systolic and diastolic blood pressures are respectively 120 mm Hg and 80 mm Hg.

\* \* \*



## Chapter 5.4

# Excretory Products and their Elimination

The component structural and functional units of the bodies of all organism are cells which have been looked as "miniature chemical factories" because of continuous metabolism taking place in these. It yields certain waste products which are, not only useless, but harmful to the cells and the body. Cells, therefore, throw out these wastes, by diffusion, into their surrounding medium. Finally, these wastes are eliminated by the body into its external environment. This is, thus an important vital activity of all organism. It is called excretion.

### Excretory organs of different organism

(1) **Protozoans** : In protozoans like Amoeba and Paramecium carbon dioxide and ammonia are mostly excreted out by diffusion through general body surface. It is considered that the contractile vacuoles also play some role in the removal of excretory products.

(2) **Sponges** : In sponges, the nitrogenous metabolic waste (ammonia) leaves the body in the outgoing water current by diffusion.

Most of the sponges are marine and have no problem of surplus water in their cells. A few sponges lie in hypotonic fresh water and have contractile vacuoles in most of their cells.

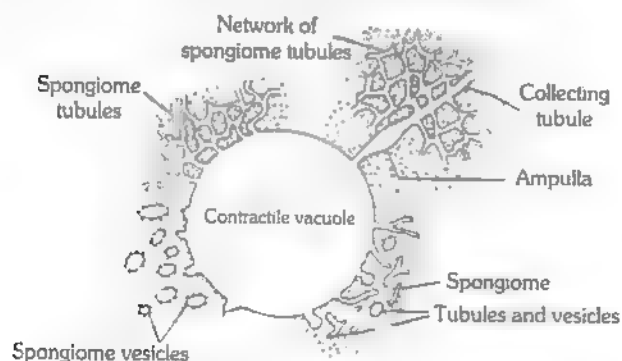


Fig : 5.4-1 Contractile vacuole in sponge

(3) **Coelenterates** : Hydra also lacks special excretory organs. The nitrogenous waste products like ammonia are removed through the general surface of the body by diffusion. Some nitrogenous waste products are also thrown along with indigestible matter through the mouth.

(4) **Platyhelminthes** : Planaria, liverfluke and tapeworm possess a large number of excretory cells called the flame cells (solenocytes) or protonephridia and long excretory ducts (also called canals of vessels). The flame cells open into the ductules which in turn open into the excretory duct.

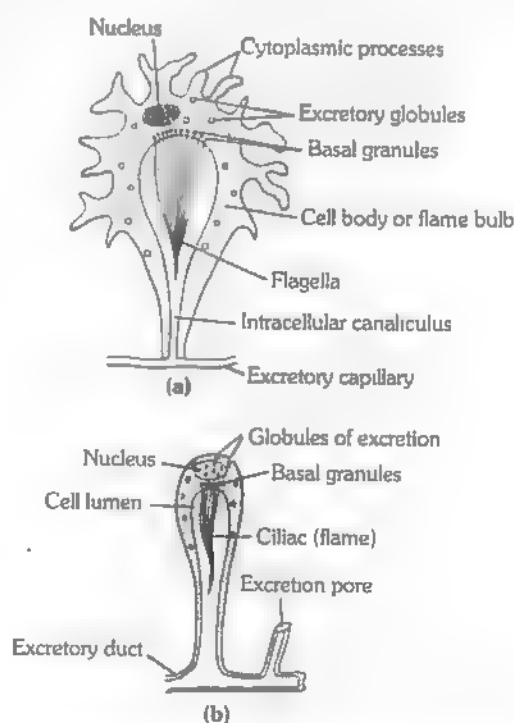


Fig : 5.4-2 Flame cell (a) Fasciola (b) Planaria

(5) **Nematoda** : The round worms such as *Ascaris* have H-shaped excretory system. It is made up of a single Renette cell, in entire length of body. It consists of two longitudinal excretory canals connected anteriorly by a network of transverse canals. A short terminal duct opens outside via excretory pore. *Ascaris* excretes both ammonia and urea.

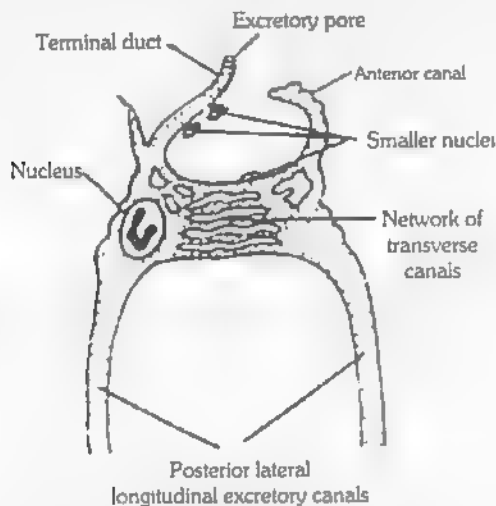


Fig : 5.4-3 Renette cell of *Ascaris*

(6) **Annelids (Earthworm)** : In earthworm excretory system is known as nephridial system, which consist of 3 types of nephridia pharyngeal, septal, and integumentary nephridia. All nephridia commonly called micronephridia. Earthworm excrete 40% urea, 20% ammonia, 40% amino acids. Earthworm is mainly ureotelic. Chloragogen cells found in coelomic fluid are also excretory in nature. Blood gland in earthworm found in 4, 5, 6 segment, serves for excretion, manufacture of blood corpuscles and Hb.

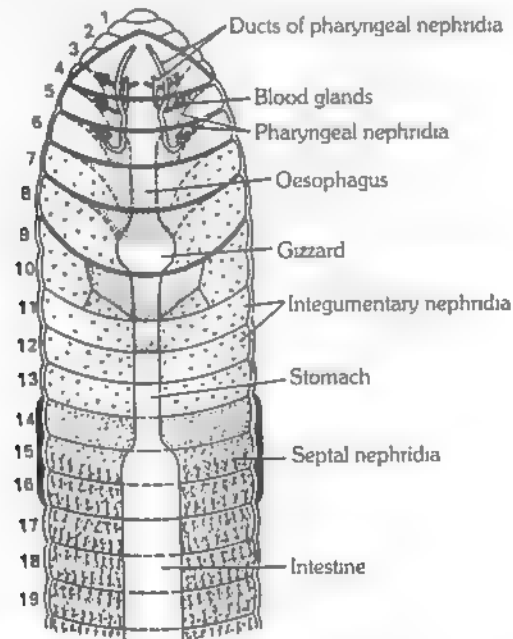


Fig : 5.4-4 Various types of nephridia and their arrangement in *Pheretima*

(7) **Arthropods** : The excretory system of the adult Prawn (crustacean) consists of a pair of antennary or green glands, a pair of lateral ducts and a single renal sac.

Insects, centipedes, millipedes and arachnids like scorpion and spider possess Malpighian tubules as their principal excretory organs. In the Malpighian tubules bicarbonates of potassium and sodium, water and uric acid are formed. A large amount of water and bicarbonates of potassium and sodium are reabsorbed by the cells of Malpighian tubules and then transferred to the blood (haemolymph). Uric acid is carried to the alimentary canal of the insect and is finally passed out through anus. Spiders and scorpions possess Malpighian tubules and coxal glands both for excretion.

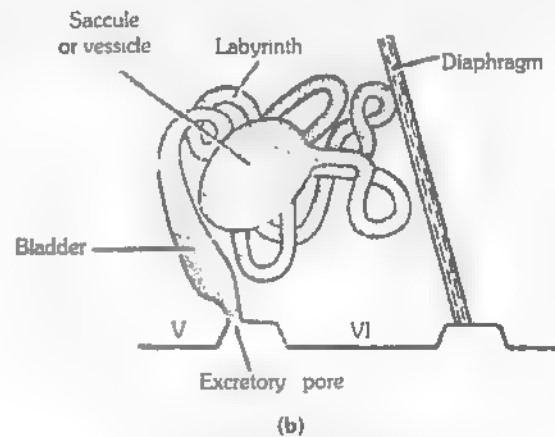
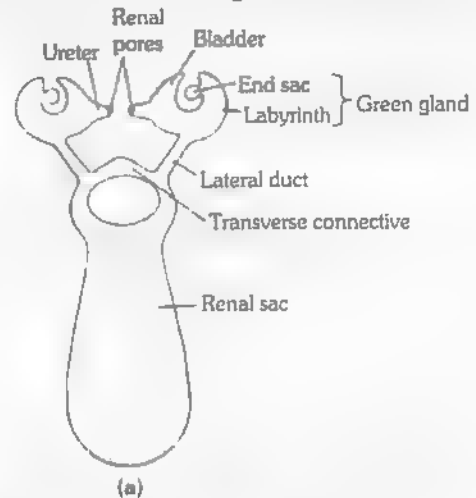


Fig : 5.4-5 (a) Antennary gland of Prawn  
(b) Coxal gland of Scorpion

(8) **Mollusca** : They have one or two pairs of kidneys or organs of bojanus and keber's organ for excretion in unlo.

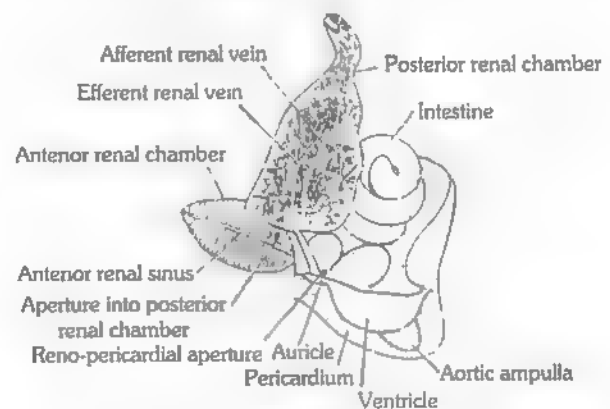


Fig : 5.4-6 Organ of Bojanus (*Pila* - mollusca)

(9) **Echinoderms** : Specialized excretory organs are absent in echinoderms (e.g., Starfish). The excretory products, chiefly ammonia, urea, and creatinine are eliminated by diffusion through

dermal branchiae (primitive gills) and tube feet. Amoeboid coelomocytes also excretory.

**Table : 5.4-1 Excretory organs of different organisms**

S.No.	Phylum	Excretory/osmoregulatory Organ/Organelle and principal $N_2$ -waste	Function	Example
<b>I Invertebrates</b>				
(1)	Protozoa	Contractile vacuole Ammonia	Ammonotelic Osmoregulatory	Amoeba Paramecium
(2)	Porifera	General surface of body	Ammonotelic	Sycon, Leucon
(3)	Coelenterata	Ammonia, General surface of body	Ammonotelic	Hydra
(4)	Platyhelminthes	flame cells (=Solenocytes) form the protonephridial system	Ammonotelic	Taenia, fasciola, planaria
(5)	Nematoda	H-shaped excretory organ Renette cells	Ammonotelic	Ascaris
(6)	Annelida	Nephridial system, (Metameric), various types	Ammonotelic	Pheretima
(7)	Arthropoda			
a	Class-Insecta	Malpighian tubule, Nephrocyte, Urinose gland (Uric acid)	Uricotelic	Periplaneta, House fly, mosquito
b	Class Crustacea	Antennary (=green) gland, Hepatopancreas Uric acid	Uricotelic	Palaemon
c	Class Arachnida	Coxal glands, Malpighian tubule, Hepatopancreas, Nephrocytes	Uricotelic, Guanine and Xanthine in small amount	Spider, Scorpion
(8)	Mollusca	(a) Kidneys or organs of Bojanus (b) Keber's organ (c) Renal organs (d) Renal sacs Ammonia in aquatic condition Excrete uric acid in terrestrial condition	Guanine Guanine Ammonotelic in aquatic, & uricotelic in terrestrial Guanine Ammonotelic Uricotelic	Unio Unio Pila, Limax Sepia
(9)	Echinodermata	Dermal branchiae (primitive gills) tube feet body surface (Ammonia), coelomocytes	Ammonotelic mainly	Cucumaria Asterias
(10)	Hemichordata	Glomerulus or proboscis gland	Ammonotelic	Balanoglossus saccoglosses
(11)	Urochordata	Neural gland, Nephrocyte	Xanthine + uric acid (Uricotelic)	Herdmania
(12)	Cephalochordata	(a) Protonephridia (b) Solenocytes (c) Brown funnel (d) Renal papilla (e) Hatschek nephridia	Ammonotelic	Amphioxus (Branchiostoma)

## Excretory products in different organisms

### (1) Waste products of protein metabolism

(i) **Amino acids** : These are end products of protein digestion absorbed into the blood from small intestine. Certain invertebrates, like some molluscs (eg *Unio*, *Limnae*, etc.) and some echinoderms (eg *Asterias*) excrete excess amino acids as such. This is called aminotelic excretion or aminotelism.

(ii) **Ammonia ( $\text{NH}_4^+$  or  $\text{NH}_3$ )** : In most animals, excess amino acids are deaminated, i.e. degraded into their keto and ammonia groups. The keto groups are used in catabolism for producing ATP, whereas ammonia is excreted as such or in other forms. Ammonia is highly toxic and highly soluble in water. Its excretion as such, therefore, requires a large amount of water. That is why, most of the aquatic arthropods, bony and freshwater fishes, amphibian tadpoles, turtles, etc excrete ammonia. This type of excretion is called ammonotelic excretion or ammonotelism.

(iii) **Urea  $\text{CO}(\text{NH}_2)_2$**  : This is less toxic and less soluble in water than ammonia. Hence, it can stay for some time in the body. Many land vertebrates (adult amphibians, mammals) and such aquatic animals which cannot afford to lose much water (e.g. elasmobranch fishes) marine bony fish, adult frog, earthworms, nematodes, turn their ammonia into urea for excretion. This type of excretion is called ureotelic excretion or ureotelism.

(iv) **Uric acid** : Animals living in dry conditions, such as land gastropods, most insects, land reptiles (snakes and lizards), birds and Kangaroo rat (mammal) etc have to conserve water in their bodies. These, therefore, synthesize crystals of uric acid from their ammonia. For the formation of uric acid xanthine oxidase enzyme is necessary. Uric acid crystals are nontoxic and almost insoluble in water. Hence, these can be retained in the body for a considerable time before being discharged from the body. Uric acid is the main nitrogenous excretory product discharged in solid form. This excretion is called uricotelic excretion or uricotelism.

(v) **Trimethylamine oxide** : Certain marine molluscs, crustaceans and teleost fishes first form trimethylamine from their ammonia by a process known as methylation. Then, the trimethylamine is oxidised to trimethylamine oxide for excretion. This oxide is soluble in water, but nontoxic.

(vi) **Guanine** : Spiders typically excrete their ammonia in the form of guanine. Some guanine is also formed in unio, penguin, birds and it is insoluble in water. Hence, no water is required for its excretion.

### (2) Waste products of nucleic acid metabolism

As a result of nucleic acid digestion, nitrogenous organic bases – purines (adenine and guanine) and pyrimidines (cytosine, thymine and uracil) – are absorbed from intestine into the blood. Most of these are excreted out. About 5% of the total excretion of body accounts for these substances. In man, purines are changed to uric acid for excretion. In most other mammals, nitrogenous organic bases are excreted in the form of allantoin. Insects, amphibians, reptiles and birds also excrete these bases in the form of uric acid. Some freshwater molluscs and crustacean arthropods excrete these in the form of ammonia.

### (3) Some sundry excretory substances (Others excretory products)

(i) **Hippuric and ornithuric acids** : Sometimes food of rabbit and other mammals may contain traces of benzoic acid, or this acid may be formed in small amounts during fat metabolism. It is highly toxic. As it is absorbed in blood, it is combined with glycine and changed into less toxic hippuric acid for excretion. In birds, benzoic acid is combined with ornithine and changed into ornithuric acid for excretion.

(ii) **Creatine and creatinine** : Muscle cells contain molecules of creatine phosphate, which are high energy molecules and serve for storage of bioenergy like ATP. It is synthesised by 3 amino acids (G.A.M.) (Glycine, Arginine and Methionine). Excess amount of this phosphate is, however, excreted out as such, or after being changed into creatinine.

## Excretory system of man

Mammalian (human) urinary system consists of a pair of kidneys, a pair of ureter, a urinary bladder and a urethra.

(1) **Kidneys** : The kidneys are dark-red, bean-shaped organs about 11 cm long, 5 cm wide and 3 cm thick, each weight about 150 gm in an adult male and about 135 gm in adult female. They are placed against the back wall of the abdominal cavity just below the diaphragm, one on either side opposite the last thoracic and first three lumbar vertebrae. The 11<sup>th</sup> and 12<sup>th</sup> pairs of ribs protect them.

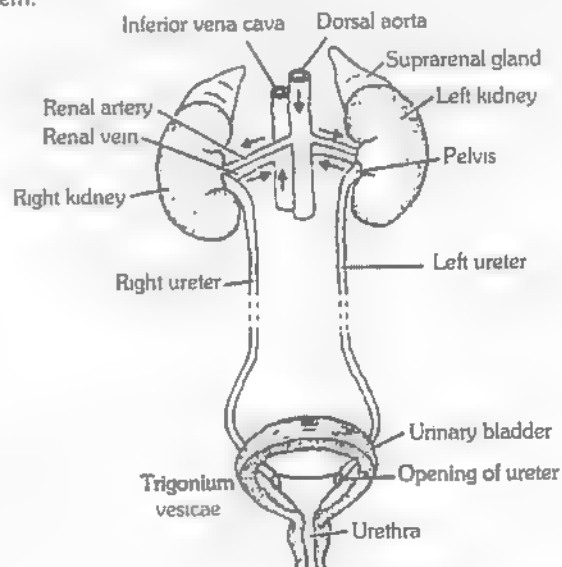


Fig : 5.4-7 Human urinary system

The kidneys are covered by peritoneum on the front (ventral) side only. thus, they are retroperitoneal. The right kidney is attached more anterior than the left in rabbit. This asymmetry is just the reverse of that found in man.

In man left kidney occurs at a slightly higher level than the right one, because right side has prominent right liver lobe. In rabbit the condition is little differ due to quadropedilism i.e. left kidney is in normal position while the right kidney shift ahead to provide place for stomach below it.

In mammals, the kidney is concavo convex. The center of concave inner surface is called as hilum or hilus which gives out a ureter. From this hilus surface the renal artery enters into the kidney, the renal vein comes out and the renal nerves enter into the kidney.

(i) **Structure of kidney** : The kidneys are metanephric in mammals. The kidney is divisible into two parts outer-cortex and inner-medulla. Three layers of tissue surround each kidney.

(a) The innermost, renal capsule made up of fibrous connective tissue.

(b) The intermediate layer, adipose capsule of fatty tissue.

(c) The outermost, renal fascia of dense connective tissue.

**Renal pyramids or medullary pyramids** : The medulla is subdivided into 8 to 18 conical masses – the renal pyramid, each having broad base towards the cortex and a narrow end called renal papilla towards the pelvis.

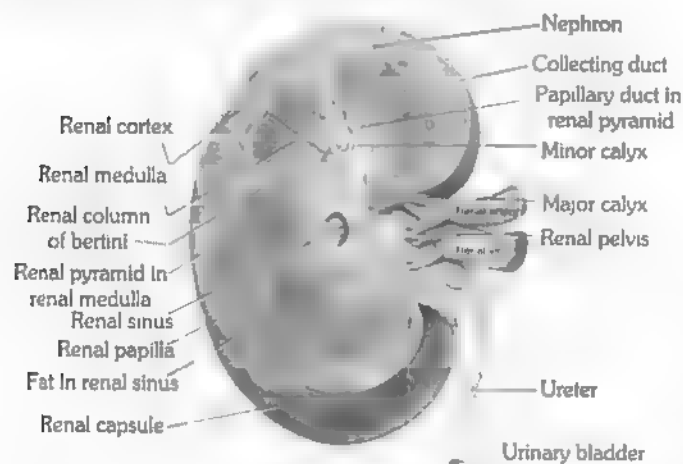


Fig : 5.4-8 L.S. of human kidney

**Path of urinary drainage** : Collecting duct → Papillary duct in renal pyramid → Minor calyx → Major calyx → Renal pelvis → Ureter → Urinary bladder

**Renal columns of Bertini** : Between the pyramids, the cortex extends into the medulla or renal columns of Bertini.

**Calyx** : Each renal papilla projects into the cavity of a minor calyx, minor calyx join to form major calyx. The major calyx open into a wide funnel like structure, the pelvis. The latter leads into the ureter. In rabbit, the pelvis is unbranched hence, it is without calyx.

In frog ventral surface of each kidney has many ciliated funnels called nephrostomes. They drain wastes from body cavity (coelom) and connect to renal veins in frog or to uriniferous tubules in tadpoles.

(ii) **Histology of kidney** : Histologically a kidney is made of innumerable thin, long, much convoluted tubular units called uriniferous tubule or nephron.

Nephron is the structural and functional unit of kidney. One human kidney may contain about one million (10 lac nephron) nephron (In rabbit each kidney bear about 2 lac nephron). In frog each kidney bears about 2 thousand nephron.

(a) **Structure of nephron** : A nephron or uriniferous tubules consist of two parts :

**Malpighian body / Renal Corpuscles** : The proximal end of each nephron forms a blind or closed, enlarged and double walled cup, the Bowman's capsules in the cortex. (name Bowman's capsule is based on English physiologist and histologist William Bowman).

Each capsule contains a network of blood capillaries the glomerulus which receives blood through afferent arteriole and the blood comes out through the efferent arteriole. The diameter of the efferent arteriole is comparatively lesser. Bowman's capsule and glomerulus receives about 20 – 25% of the cardiac out put (blood) at rest.

The composite structure of Bowman's capsule and glomerulus is known as Malpighian body or Malpighian corpuscles after the Italian microscopist Marcello Malpighi.

**Tubule** : The tubule is differentiated into 3 parts P.C.T., Henle's loop and D.C.T.

The Bowman's capsule opens into a proximal convoluted tubule (P.C.T.) the anterior part of the P.C.T. is more coiled where as its posterior part is almost straight. The P.C.T. opens into a Henle's loop. The Henle's loop is a U-shaped structure or makes hair pin turn, which has a distinct descending limb and an ascending limb. The ascending limb opens into the distal convoluted tubule. The D.C.T. is a coiled structure. Many D.C.T. unite to form a collecting duct. The collecting ducts of one pyramid unite to form a duct of Bellini. The duct of Bellini lead into the pelvis part.

(b) **Arrangement of nephron** : The malpighian body and most of the P.C.T. and D.C.T. are situated in the cortex. Henle's loop and collecting ducts are found in the medulla.

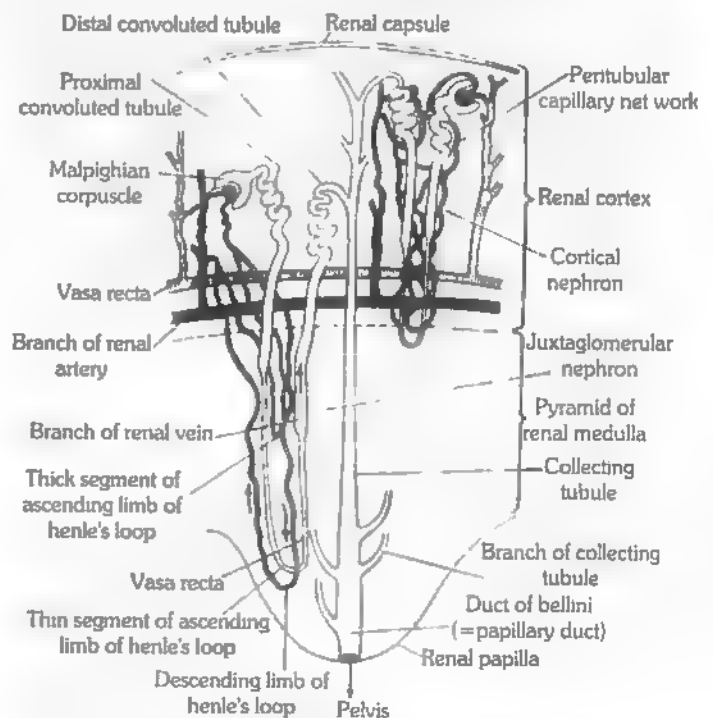


Fig : 5.4-9 Position, structure and blood supply of cortical and juxtamedullary nephrons in a mammalian kidney

**Vasa recta :** The efferent arteriole of juxta-glomerular nephron forms a peritubular capillary system around the Henle's loop which is called vasa recta. Each of the vasa recta makes U turn at the inner most part of the medulla and return to the venous circulation near the junction of medulla and cortex. The efferent arteriole and peritubular capillaries technically constitute a renal portal system. All amniotes as reptiles, birds and mammals have this renal portal system of efferent arteriole and peritubular capillaries.

(c) **Types of nephron :** Nephrons are of two types cortical and juxtamedullary, with regard to their location in the kidney. The cortical nephrons form about 80% to 85% of total nephron.

Remaining 15 – 20% are juxta medullary nephron.

**Table : 5.4-2 Differences between cortical and Juxtamedullary nephrons**

S.No.	Cortical Nephrons	Juxtamedullary Nephron
1.	Form 80 – 85% of total nephrons.	Form only 15 – 20% of total nephrons.
2.	Are small in size.	Are large in size
3.	Lie mainly in the renal cortex.	Have Bowman's capsules in the cortex near its junction with the medulla
4.	Henle's loops are very short and extend only a little into the medulla	Henle's loop are very long and extend deep into the medulla.
5.	Control plasma volume when water supply is normal	Control plasma volume when water supply is short.
6.	Glomeruli in superficial region of cortex	Glomeruli deep in cortex
7.	Blood supply from peritubular capillaries only.	Blood supply from both peritubular capillaries, and vasa recta.

#### (d) Histology of nephron

**Glomerulus :** Glomerulus is a network of upto 50 parallel branching and anastomosing capillaries covered by endothelium, basement membrane and epithelium made of podocytes which has slit pores that restrict passage of colloids. However, small molecules and water can easily pass through them into the P.C.T.

**Bowman's capsule :** The podocytes forming the inner wall of the Bowman's capsule have gaps (about 25 nm wide) the slit pores.

The outer wall of the Bowman's capsule consists of unspecialized squamous epithelium (flattened).

**Proximal convoluted tube :** P.C.T. is made up of simple cuboidal epithelium . It has microvilli so it is also known as brush border epithelium. P.C.T. is most important site for selective reabsorption.

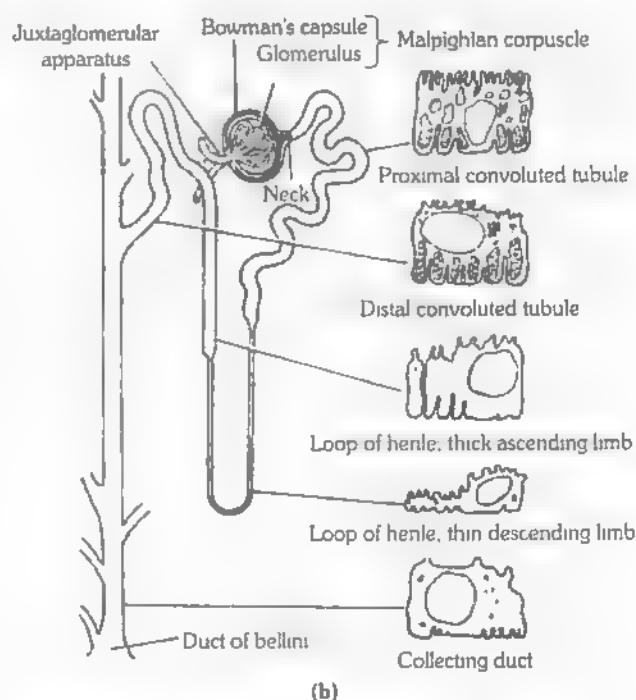
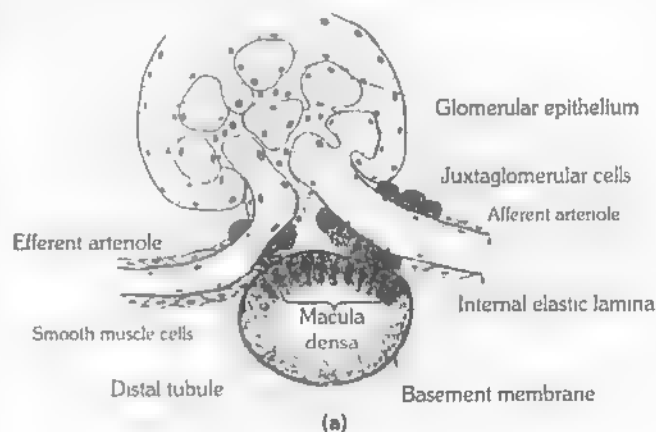
**Loop of Henle :** The epithelium of descending limb of loop of Henle is very thin and composed of squamous epithelium and ascending limb is made up of two parts. First is thin ascending limb lined by squamous epithelium and second thick ascending limb

lined by cuboidal epithelium. The ascending limb is impermeable to water and permeable to NaCl.

**Distal convoluted tube :** D.C.T. is made up of cuboidal epithelium which is glandular in nature.

**Collecting ducts :** The collecting ducts are lined by cuboidal epithelium in different regions. At intervals, the cuboidal cells are ciliated.

**Juxta-glomerular apparatus :** This specialized cellular apparatus is located where the distal convoluted tubule passes close to the Bowman's capsule and afferent arteriole. Cells of the D.C.T. epithelium in contact with afferent arteriole are denser than other epithelial cells known as macula densa. Macula densa has special Lacis cell or Polkisson's cell. These cells secrete renin hormone that modulate blood pressure and thus renal blood flow and G.F.R. are regulated.



**Fig : 5.4-10 (a) Juxta glomerular apparatus (b) Juxtamedullary nephron and epithelial cells in the wall of its various parts**



**Origin and types of kidneys in different vertebrate**

Kidney tubules (nephrons) arise in the embryo in a linear series from a special part of mesoderm called mesomere or nephrotome.

Number, complexity and arrangement of nephrons differ in different groups of vertebrates. A nephron is differentiated into three parts – pentoneal funnel, tubule and malpighian body. Peritoneal funnel (nephrostome) are normally present in embryos and larvae and considered as vestigial organ of hypothetical primitive kidneys.

(1) **Archeonephros kidney** : Archeonephros is the name given to the hypothetical primitive kidney of ancestral vertebrate. It is also called as holonephros or complete kidney. (It extended entire length of coelom) Its tubules are segmentally arranged and nephrostome is present. Glomerulus is external (without capsule). Its duct is called as archeonephric duct. e.g., Larva of myxine and some apodan amphibians.

Modern vertebrates exhibits three different kinds of adult kidney Pronephros, Mesonephros and Metanephros.

(i) **Pronephros** : It originates from the anterior part of the nephrotome. It is also termed head kidney due to its anterior position. There are only 3 pronephrine tubule (nephron) in frog embryo, 7 in human embryo, and about 12 in chick embryo which are segmentary arranged. Nephrostome is present, glomerulus is external and unite to form glomus in some cases. Duct is pronephric duct or mullerian duct. A pair of pronephros appear in all vertebrate embryos but they becomes functional kidneys in adult myxine and embryos of all anamniotes (fish, amphibian). This kidney is found as transitory kidney in all vertebrates embryos.

(ii) **Mesonephros** : It originates from the middle part of the nephrotome. Duct is mesonephric or Wolffian duct. Nephrostome is absent except some embryos of anamniotes. Example – In amniotes (reptiles, birds and mammals) mesonephros is functional only in the embryos, replaced by metanephros in the adult. In anamniotes (fishes and amphibian) mesonephros is functional in both embryo as well as adults. Also found in adult petromyzon.

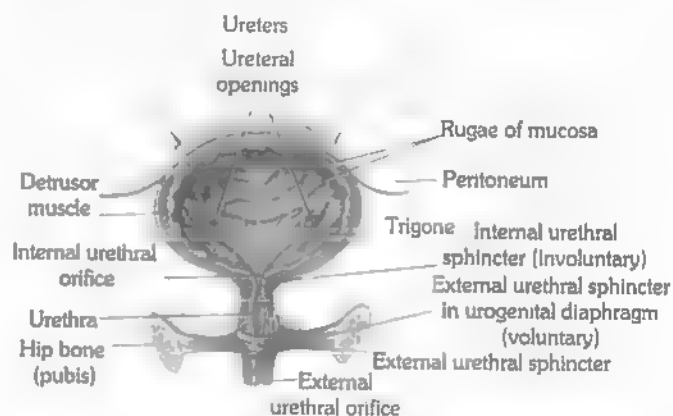
□ In fish and amphibians, tubules extend through length of coelom behind pronephros and formed from entire nephrotome left behind the pronephrus called opisthonephric kidney. The opisthonephric kidney specially in males is differentiated into anterior genital and post renal part.

□ In frog mesonephric duct is also known as Bidder's canal which carry sperm and urine both.

(iii) **Metanephros** : It originates from the posterior part of the nephrotome. When metanephric tubules develop, all the mesonephric tubules disappear except those associated with the testes in male and forming vasa efferentia. Nephrostome absent. A thin, U-shaped loop of Henle forms between P.C.T. and D.C.T. which is incomplete in Reptiles and Birds and well developed in mammals. Duct is metanephric or ureter. Reproductive duct is separate. The kidney is highly compact which possesses innumerable nephrons. Example – All amniotes – Reptile, Birds and mammal.

(2) **Ureters** : From the hilum of each kidney emerges a whitish tube the ureter. The ureters are about 28 cm long. Their wall consists of transitional epithelium surrounded by a layer of muscle fibres. Openings of the two ureters in the bladder are separate, but closely placed. These are oblique, so that the urine cannot regurgitate into the ureters when the bladder contracts. Peristalsis of ureters also checks regurgitation of urine. Like kidneys, the ureters are retroperitoneal.

(3) **Urinary bladder and Urethra** : The urinary bladder is pear-shaped hollow muscular organ situated in pelvic cavity, which is made up of smooth and involuntary muscles. The muscles are also known as detrusor muscles (muscles that has the action of expelling a substance). The lower part or neck of the bladder leads into the urethra. There is a smooth triangular area, called trigonium vesicae. The lumen of the urinary bladder is lined by transitional epithelium which has great power of stretching. The neck of bladder is guarded by two sphincters, inner is involuntary controlled by spinal reflex and outer is voluntary controlled by cerebral cortex. A person feels the sensation of micturition when the quantity of urine in the bladder is about 300 c.c. The average capacity of urinary bladder is 700 – 800 ml. In general, urinary bladder capacity is smaller in females because the uterus occupies the space just superior to bladder. Mucosa of bladder with folds called rugae. (rugae also present in stomach and vagina).



**Fig : 5.4-11 Parts of ureters, trigone of the bladder, sphincters and urethra**

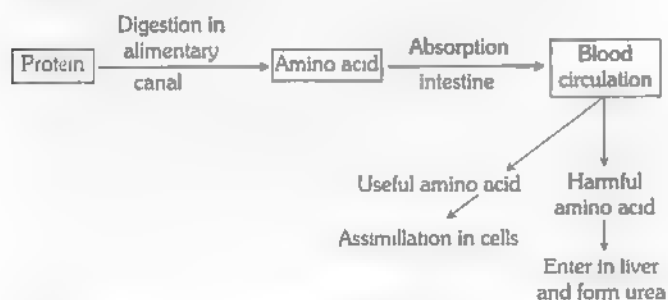
(4) **Urethra** : The urinary bladder leads into the urethra. In female, it is quite short, only about 3 to 5 cm long, and carries only urine. It opens by urethral orifice, or urinary aperture in the vulva in front of the vaginal or genital aperture. In a male urethra is much longer, about 20 cm and carries urine as well as spermatic fluid. It passes through the prostate gland and the penis. It opens out at the tip of the penis by urogenital aperture. In males the epithelium of spongy urethra is stratified or pseudostratified columnar epithelia, except near external urethral orifice, which is non keratinized stratified squamous epithelia. The prostatic urethra is lined by transitional epithelia, while membranous urethra is lined by pseudostratified columnar.

Table : 5.4-3 Differences between male and female urethra

S. No.	Male urethra	Female urethra
1.	It is about 20 cm long.	It is just 3 – 5 cm long.
2.	It has 3 regions : prostatic urethra (3–4 cm), membranous (1 cm) and penile (15 cm)	It is not differentiated into regions.
3.	It opens out at the tip of the penis by urinogenital aperture.	It opens into the vulva by urinary aperture
4.	It carries urine as well as semen to the exterior.	It carries only urine to the exterior
5.	It has 2 sphincters.	It has a single sphincter.

## Physiology of excretion

Major nitrogenous excretory substance in frog, rabbit and human is urea, i.e. these are ureotelic animals. The excretory physiology in these animals may be considered under two phases, viz urea synthesis and formation and excretion of urine.



**Synthesis of urea in liver :** Urea is formed in liver by two processes.

- (1) Deamination      (2) Ornithine cycle

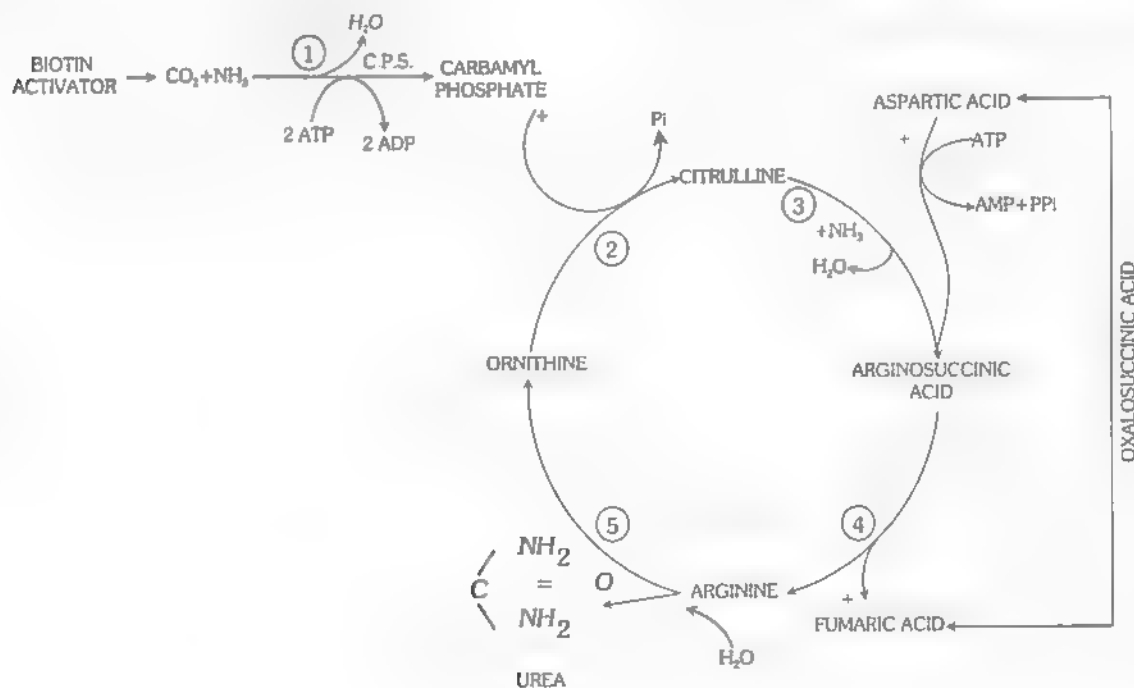
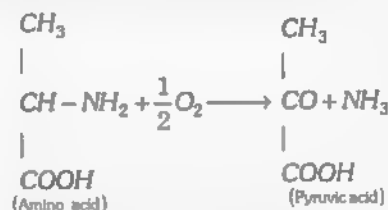


Fig : 5.4-12 Ornithine cycle

(1) **Deamination :** The amino acid is oxidised using oxygen. This results in removal of the amino group ( $\text{NH}_2$ ) and leaves pyruvic acid. The pyruvic acid can enter the Krebs cycle and be used as a source of energy in cell respiration. The amino group is converted to ammonia ( $\text{NH}_3$ ) during deamination. Deamination is also known as oxidative deamination.



With the help of a number of enzymes and energy of A.T.P. two molecules of ammonia are combined with  $\text{CO}_2$  to form urea according to the ornithine cycle.

(2) **Ornithine cycle (Kreb-Henseleit cycle) :** In liver one molecule of  $\text{CO}_2$  is activated by biotin and combines with two molecules of  $\text{NH}_3$  in the presence of carbamyl phosphate synthetase enzyme (C.P.S.) and 2 ATP to form carbamyl phosphate and one molecule of  $\text{H}_2\text{O}$  is released. Carbamyl phosphate react with ornithine and form citrulline. Citrulline combines with another molecule of ammonia and form arginine. Arginine is broken into urea and ornithine in the presence of an enzyme arginase and water.



Liver cells, thus, continuously remove ammonia and some  $\text{CO}_2$  from blood and release urea into the blood. Kidneys continuously remove urea from the blood to excrete it in urine.

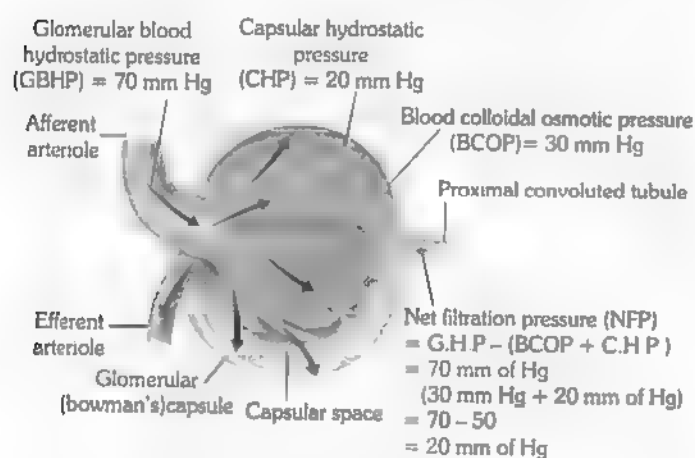
**Urine formation :** Urine formation occurs in the kidneys. It involves three processes glomerular filtration, reabsorption and tubular secretion.

**(1) Ultra filtration (Starling's hypothesis)**

(i) It is a passive process which takes place from the glomerulus into the Bowman's capsule. The glomerular epithelium has various micropores (diameter = 50 – 100 nm or 0.05 – 0.1  $\mu$ m) which increase the rate of filtration.

(ii) The non colloidal part of the plasma as urea, water, glucose, salts, vitamin, minerals, nitrogenous waste are forced out from the glomerular capillaries into the Bowman's capsule by the high pressure of the blood in the glomerular capillaries. The pressure and resistance is high because the glomerular capillaries are narrower than the afferent renal arteries. Glomerular capillaries are about 50 times more permeable than capillaries elsewhere. Pressure is highest in glomerular capillaries than in capillaries elsewhere, produce more filtrate.

(iii) The effective filtration pressure that causes ultrafiltration is determined by three pressures.



**Fig : 5.4-13 Ultra filtration**

**(a) Glomerular blood hydrostatic pressure (G.B.H.P.) :** Hydrostatic pressure is force that a fluid under pressure exerts against the walls of its container.

$$G.B.H.P. = +70 \text{ mm Hg.}$$

**(b) Blood colloidal osmotic pressure (B.C.O.P.) :** The B.C.O.P. is the osmotic pressure created in the blood of glomerular capillaries due to plasma proteins albumin, globulin, and fibrinogen. It resists the filtration of fluid from the capillaries.

$$B.C.O.P. = 30 \text{ mm Hg.}$$

$$B.C.O.P. \text{ in other body capillaries is } 25 \text{ mm Hg}$$

**(c) Capsular hydrostatic pressure (C.H.P.) :** C.H.P. is the pressure caused by fluid (filtrate) that reaches into Bowman's capsule and resists filtration.

$$C.H.P. = 20 \text{ mm Hg.}$$

**Effective filtration pressure (E.F.P.)/Net filtration pressure (N.F.P.) :** E.F.P. is glomerular blood hydrostatic pressure minus the colloidal osmotic pressure of blood and capsular hydrostatic pressure.

$$E.F.P. = G.B.H.P. - (B.C.O.P. + C.H.P.)$$

$$= 70 \text{ mm Hg} - (30 \text{ mm Hg} + 20 \text{ mm Hg})$$

$$= 70 - 50$$

$$E.F.P. = 20 \text{ mm Hg}$$

□ Net opposing filtration pressure

$$(N.O.F.P.) = B.C.O.P. + C.H.P.$$

$$= 50 \text{ mm Hg}$$

**Glomerular filtrate :** The plasma fluid that filters out from glomerular capillaries into Bowman's capsule of nephrons is called glomerular filtrate. It is a non colloidal part and possess urea, water, glucose, amino acid, vitamins, fatty acid, uric acid, creatine, creatinine, toxins, salts etc.

R.B.Cs, W.B.Cs, platelets and plasma proteins are the colloidal part of the blood and do not filtered out from glomerulus. Glomerular filtrate is isotonic to blood plasma.

**Glomerular filtrate or Nephric filtrate**

$$= \text{Blood} - (\text{Blood cells} + \text{Plasma protein})$$

or

$$= \text{Blood} - (\text{R.B.Cs} + \text{W.B.Cs} + \text{platelets} + \text{plasma protein})$$

or

$$= \text{Plasma} - \text{Protein}$$

**Glomerular filtration rate (G.F.R.) :** G.F.R. is the amount of filtrate formed per minute in all nephrons of the paired kidney. There is a sexual difference. In male the rate is 120 – 125 ml/min, in female it is 110 ml/min. G.F.R. is affected by volume of circulating blood, neural activity, stretch response to pressure of the wall of the arteriole

180 litre of filtrate is formed per day, out of it, only 1.5 litre of urine is produced per day which is 0.8% of the total filtrate.

**Renal plasma flow :** About 1250 ml (25% of cardiac output or total blood) blood circulates through kidneys each minute and of this blood, about 670 ml is the plasma. The latter is called the renal plasma flow (R.P.F.)

$$R.P.F. = 670 \text{ ml.}$$

**Filtration fraction :** This is the ratio of G.F.R. to R.P.F., and it is called filtration fraction.

$$\text{Filtration fraction} = \frac{G.F.R.}{R.P.F.} = \frac{120}{670} = 0.17$$

**(2) Selective reabsorption :** Discovered by Richard and supporters.

**Proximal convoluted tubule :** P.C.T. is the pivotal site for reabsorption. Glucose, amino acid and  $\text{Na}^+$ ,  $\text{K}^+$  ions are reabsorbed by active transport.  $\text{Cl}^-$  are reabsorbed by passive transport following the positively charged ions.

Active uptake of ions reduces the concentration of the filtrate and an equivalent amount of water passes into the peritubular capillaries by osmosis. (Here 80% water is reabsorbed by passive transport. It is also known as obligatory water reabsorption). Most of the important buffer bicarbonate ( $\text{HCO}_3^-$ ) is also reabsorbed from the filtrate. P.C.T. absorb nearly 80–90% of filtered bicarbonate. Some urea is reabsorbed by diffusion. The rest remain in the filtrate to be removed in the urine.

**Henle's loop :** See counter current mechanism.

**Distal convoluted tubule :** When the level of plasma water falls, the posterior pituitary lobe release the antidiuretic hormone (ADH) which increases the permeability of the distal convoluted tubule and the collecting duct to water. Water is reabsorbed from the filtrate by osmosis and a reduced amount of concentrated urine is produced (Here 13% water is reabsorbed by facultative reabsorption)

The distal convoluted tubule and the collecting duct actively reabsorbs sodium from the filtrate under influence of the adrenal hormone aldosterone which makes their walls permeable to ions. The reabsorption of  $\text{Na}^+$  brings about the uptake of an osmotically equivalent amount of water. But duct of Bellini is relatively impermeable to water. Bicarbonate ions are also reabsorbed in D.C.T.

(3) **Tubular secretion :** It occurs as under –

(i) Creatinine, hippuric acid and foreign substances (pigments, drugs including penicillin) are actively secreted into the filtrate in the PCT from the interstitial fluid. Hydrogen ions and ammonia ( $\text{NH}_3$ ) are also secreted into the PCT.

(ii) Potassium, hydrogen,  $\text{NH}_4^+$  and  $\text{HCO}_3^-$  ions are secreted by active transport, into the filtrate in the DCT.

(iii) Urea enters the filtrate by diffusion in the thin region of the ascending limb of Henle's loop.

Removal of  $\text{H}^+$  and  $\text{NH}_4^+$  from the blood in the PCT and DCT helps to maintain the pH of the blood between 6 to 8. Any variation from this range is dangerous.

Tubular secretion probably plays only a minor role in the function of human kidneys, but in animals, such as marine fish and desert amphibians which lack glomeruli and Bowman's capsules, tubular secretion is the only mode of excretion. When the blood pressure, and consequently the filtration pressure, drop below a certain level, filtration stops and urine is formed by tubular secretion only.

**High threshold substances :** Such substances are absorbed almost all. Example – Sugar, amino acids, vitamins,  $\text{HCO}_3^-$  and  $\text{Na}^+$  etc.

**Low threshold substances :** They are absorbed in low concentration. Example – Urea, phosphate, uric acid,  $\text{H}^+$ ,  $\text{K}^+$ .

**Non threshold substances :** They are not reabsorbed. Example – Creatinine and hippuric acid.

**Diuretic substances :** Normally, the amount of urine formed depends on the intake of water, dietary constituents, environmental temperature, mental and physiological states of the person. However, there are some substances which increase the volume of urine to be excreted, these substances are called diuretic substances. Example – Tea, Coffee, alcohol etc.

**Mechanism of urine concentration (Counter current mechanism of urine concentration) :** Mammals form hypertonic urine. The urine is made hypertonic with the help of counter current multiplier system. This process takes place in the Henle's loop and vasa recta and it involves mainly  $\text{Na}^+$  and  $\text{Cl}^-$ . In P.C.T. urine is isotonic. The descending limb of loop of Henle is permeable to water. Its surrounding tissue fluid is hypertonic. Hence, the water moves out and the  $\text{Na}^+$  and  $\text{Cl}^-$  moves in the descending limb by passive transport. Therefore, the filtrate in the descending limb finally becomes hypertonic.

The ascending limb of the Henle's loop is impermeable to the water. The  $\text{Na}^+$  and  $\text{Cl}^-$  moves out by active transport. Hence the filtrate finally becomes hypotonic. The  $\text{Na}^+$  and  $\text{Cl}^-$  re-enter into the descending limb of the Henle's loop. The collecting duct always passes through the hypertonic tissue fluid. Hence, water comes out osmotically making the filtrate hypertonic. Now in collecting duct glomerular filtrate is known as urine. Term urine first time used in collecting duct.

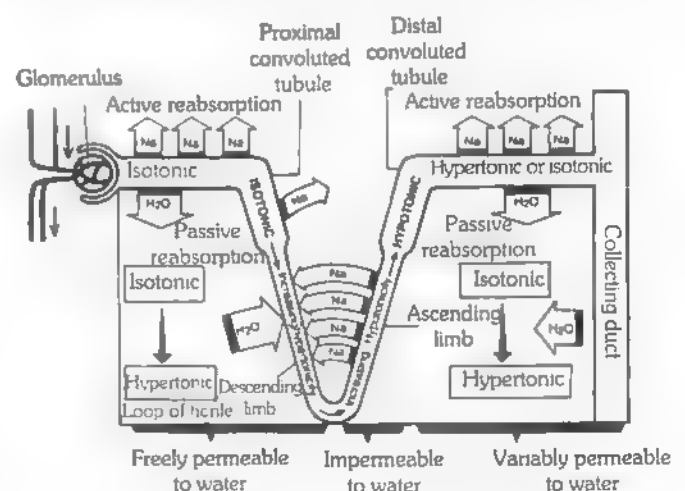


Fig : 5.4-14 Counter current multiplier in Henle's loop

Table : 5.4-4 Summary of events occurring in a nephron

S.No.	Materials transferred in traces	Nephron region	Process involved	Mechanism
1	Glucose, Amino acids, protein albumin, Vitamins, Hormones, $\text{Na}^+$ , $\text{K}^+$ , $\text{Mg}^{2+}$ , $\text{Ca}^{+2}$ , $\text{H}_2\text{O}$ , $\text{HCO}_3^-$ , Urea, Uric Acid, Creatinine, Ketone Bodies.	Bowman's capsule	Glomerular filtration	Ultrafiltration
2	Glucose, Amino Acids, Hormones, Vitamins, $\text{Na}^+$ , $\text{K}^+$ , $\text{Mg}^{2+}$ , $\text{Ca}^{+2}$	Proximal convoluted tubule	Reabsorption	Active transport
3	$\text{Cl}^-$	Proximal convoluted tubule	Reabsorption	Passive transport
4	$\text{H}_2\text{O}$	Proximal convoluted tubule	Reabsorption	Osmosis
5	Urea	Proximal convoluted tubule	Reabsorption	Diffusion
6	$\text{H}_2\text{O}$	Narrow region of descending limb of Henle's loop	Reabsorption	Osmosis
7	$\text{Na}^+$ , $\text{K}^+$ , $\text{Mg}^{+2}$ , $\text{Ca}^{+2}$ , $\text{Cl}^-$	Narrow region of ascending limb of Henle's loop	Reabsorption	Diffusion
8	Inorganic ions as above	Wide part of ascending limb of Henle's loop	Reabsorption	Active transport
9	$\text{H}_2\text{O}$	Distal convoluted tubule, collecting tubule, collecting duct	Reabsorption with ADH Help	Osmosis
10	$\text{Na}^+$	Distal convoluted tubule, collecting tubule, collecting duct	Reabsorption with aldosterone help reabsorption secretion	Active transport
11	Urea	Last part of collecting duct	Reabsorption with aldosterone help reabsorption secretion	Diffusion
12	Creatinine, Hippuric Acid Foreign substances	Proximal convoluted tubule	Reabsorption with aldosterone help reabsorption secretion	Active transport
13	$\text{K}^+$ , $\text{H}^+$	Distal convoluted tubule	Reabsorption with aldosterone help reabsorption secretion	Active transport
14	$\text{NH}_3$	Distal convoluted tubule	Reabsorption with aldosterone help reabsorption secretion	Diffusion
15	Urea	Ascending limb of Henle's loop (Thin part)	Reabsorption with aldosterone help reabsorption secretion	Diffusion

## Urine

The fluid and dissolved waste substances excreted by the kidneys constitute urine.

**Quantity :** An adult man normally passes about 1 to 1.8 litres of urine in 24 hours. The volume of urine depends upon (i) the fluid intake, (ii) level of physical activity, (iii) type of food taken and (iv) environmental temperature increase urine output. Less fluid intake and profuse sweating due to heavy physical work and high temperature reduce urine output. Certain substances such as tea, coffee and alcohol, increase urine output. These are said to be diuretic.

**Physical properties :** Urine is transparent yellowish fluid, but becomes turbid (cloudy) on standing, its colour depends on its concentration. Its colour is due to a pigment urochrome derived from the breakdown of haemoglobin from the worn-out RBCs. Colour of the urine is altered by certain materials taken such as beet, vitamin B complex and some drugs and diseases. It is hypertonic to blood plasma. Its specific gravity ranges between 1.001 to 1.035, being slightly higher than that of water. Its pH is 6. It depends on the diet. High protein food and fruits increase acidity whereas vegetables increase alkalinity. Urine has a characteristic unpleasant odour. If allowed to stand, urea is degraded by bacteria to ammonia which imparts a strong smell to urine.

**Chemical composition :** Urine consists of water and organic and inorganic substances. Water alone forms about 95% of it, other substances form only 5%. The organic substances are

mainly nitrogenous organic compounds include urea, uric acid, creatinine and hippuric acid. Of these, urea is the principal component of human urine. The non nitrogenous organic compounds include vitamin C, oxalic acid, phenolic substances include ammonia, and mineral salts such as chlorides, sulphates and phosphates of sodium, potassium, calcium and magnesium. Sodium chloride is the principal mineral salt of the urine. Urine also contains some other substances, such as pigments and drugs, and some epithelial cells, leucocytes, mucin, enzymes, and hormones.

**Abnormal materials :** Presence of proteins (albumins), bile salts, bile pigments, ketone bodies, blood, pus, microbes and more than a trace of glucose in the urine is pathological condition. Presence of glucose, protein, blood, ketone bodies and pus in the urine is called glucosuria, proteinuria, haematuria, ketonuria and pyuria respectively.

**Renal threshold :** A negligible amount of glucose is present in the urine. The highest concentration of a substance in the blood upto which it is fully reabsorbed from the glomerular filtrate is called its threshold. If its concentration in the blood exceeds its renal threshold, some of the filtered out substance is not reabsorbed and is excreted in the urine. For example, the renal threshold of glucose is 180 mg. per 100 ml. of blood. If its blood level exceeds 180 mg., some of the filtered out glucose is not reabsorbed and is passed in urine.

**Conduction of urine and Micturition :** Urine is produced and drained continuously by the nephrons into the renal pelvis. From here, it is carried down the ureters by peristaltic waves into trigonum vesicae and then into the body of the urinary bladder. The bladder serves to store the urine temporarily and also to pass it out at suitable intervals. The process of passing out urine from the urinary bladder is called urination or micturition. As urine collects, the muscular walls of the bladder distend to accommodate it. Distension of its walls stimulates the sensory nerve endings in the bladder wall and this sets up reflexes, which cause an urge to pass out urine. During the discharge of the urine, the bladder and urethral sphincters relax and the smooth muscles of the bladder wall gradually contract. This slowly drives the urine from the bladder through the urethra to the exterior. Reflux of the urine into the ureters is prevented because the terminal parts of the ureters pass obliquely through the bladder wall and are consequently closed when the bladder wall contracts around them. Relaxation and contraction of the urinary bladder are caused by impulses from the sympathetic and parasympathetic nerve fibres.

Micturition may be voluntarily postponed for some time until the pressure in the bladder rises too high to control. Micturition may also be voluntarily achieved even before sufficient urine has accumulated in the bladder. Normally an urge for micturition starts when the bladder is a little more than half full of urine.

**Table : 5.4-5 Urine constituents in man (in gram)**

1.	Total volume	1,200 ml – per 24 h
2.	Water	1,140 ml
3.	Total solids	50 gm
4.	Glucose	0
5.	Protein	0
6.	Ketones	0
7.	Urea	30 gm
8.	Creatinine	1.6 gm
9.	Creatine	0.1 gm
10.	Hippuric acid	0.7 gm
11.	Urobilinogen	0.4 mg
12.	Porphyrins	50 – 300 µg
13.	Uric acid	0.7 gm
14.	NaCl	15.0 gm
15.	K	3.3 gm
16.	Ca	0.3 gm
17.	Mg	0.1 gm
18.	Fe	0.1 gm 0.005 gm
19.	SO <sub>4</sub>	2.5 gm
20.	PO <sub>4</sub>	2.5 gm

**Table : 5.4-6 Urine constituents in man (in %)**

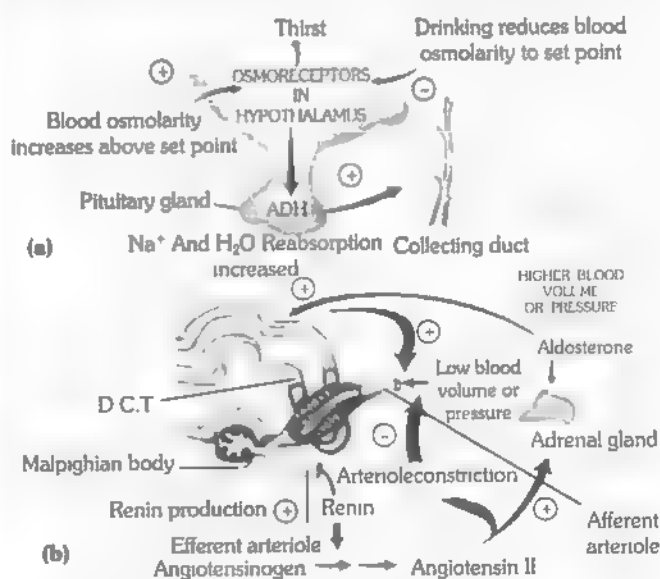
1.	Water	96%
2.	Urea	2%
3.	Uric acid	0.2%
4.	NH <sub>3</sub>	0.25%
5.	Creatinine	0.5%
6.	Hippuric acid	0.025%
7.	Salt	1%

## Hormonal control of renal function

Hormonal controls of the kidney function by negative feedback circuits can be identified :

(1) **Control by antidiuretic hormone (ADH) :** ADH, produced in the hypothalamus of the brain and released into the blood stream from the pituitary gland, enhances fluid retention by making the kidneys reabsorb more water. The release of ADH is triggered when osmoreceptors in the hypothalamus detect an increase in the osmolarity of the blood above a set point of 300 mosm L<sup>-1</sup>. In this situation, the osmoreceptor cells also promote thirst. Drinking reduces the osmolarity of the blood, which inhibits the secretion of ADH, thereby completing the feedback circuit.

(2) **Control by Juxtaglomerular apparatus (JGA) : (Low Blood pressure triggers the Renin-angiotensin pathway)** JGA operates a multihormonal Renin-Angiotensin-Aldosterone System (RAAS). The JGA responds to a decrease in blood pressure or blood volume in the afferent arteriole of the glomerulus and releases an hormone, renin into the blood stream. In the blood, renin initiates chemical reactions that convert a plasma protein, called angiotensinogen, to a peptide, called angiotensin II, which works as a hormone. Angiotensin II increases blood pressure by causing arterioles to constrict. It also increases blood volume in two ways – firstly, by signaling the proximal convoluted tubules to reabsorb more NaCl and water, and secondly, by stimulating the adrenal gland to release aldosterone, a hormone that induces the distal convoluted tubule to reabsorb more Na<sup>+</sup> and water. This leads to an increase in blood volume and pressure, completing the feedback circuit by supporting the release of renin.



**Fig : 5.4-15 Regulation of renal function by feedback circuits (a) Control by ADH (b) Control by RAAS**

(3) **Parathormone :** The hormone increases blood Ca<sup>++</sup> (Hypercalcaemia) and decreases PO<sub>4</sub> accordingly, it increases absorption of Ca<sup>+</sup>, increases excretion of PO<sub>4</sub>.

(4) **Thyroidal calcitonin :** It increases excretion of Ca<sup>++</sup> in the kidney.

(5) **Prostaglandin** : The renal pyramids produce fatty acids of prostaglandins (P.G.) which participates in blood pressure regulation.

(6) **Erythropoietin** : It is secreted by juxtaglomerular apparatus and plays an important role in erythropoiesis (blood production).

**Table : 5.4-7 Differences between Rennin and Renin**

S.No.	Rennin	Renin
1.	It is secreted by peptic (zymogen) cells of gastric glands into the stomach.	It is secreted by specialised cells in the afferent arterioles of the kidney cortex.
2.	Its secretion is stimulated by food.	Its secretion is stimulated by a reduction of $\text{Na}^+$ level in tissue fluid
3.	It is secreted as an inactive form prorennin which is activated to rennin by $\text{HCl}$ .	It is secreted as renin.
4.	It is a proteolytic enzyme.	It is a hormone that acts as an enzyme
5.	It helps in the digestion of milk protein casein.	It converts the protein angiotensinogen into angiotensin

### Homeostatic regulatory functions of kidneys

By continuously eliminating metabolic wastes and other impurities, and even the surplus quantity of useful materials from blood plasma in the form of urine, kidneys play a vital role in homeostasis. Kidneys also operate certain other homeostatic regulatory mechanisms. Proper maintenance of the internal environment is known as homeostasis. All regulatory functions of kidneys can be enumerated as follows –

(1) **Osmoregulation** : Being the universal solvent, water is the actual vehicle in ECF to transport materials between various parts of body. Water volume in ECF tends to vary considerably due to several reason, such as drinking, perspiration, diarrhoea, vomiting, etc. As described in previous pages, the kidneys maintain the water balance in ECF by diluting or concentrating urine.

(2) **Regulation of osmotic pressure** : Osmolality of cytoplasm is mainly due to proteins and potassium and phosphate ions, whereas that of the ECF is mainly due to sodium, chloride and bicarbonate ions. Inspite of marked difference in chemical composition, the two fluids – intracellular (cytoplasm) and extracellular (interstitium) – must be isotonic, because if ECF becomes hypotonic, cells will absorb water, swell retaining appropriate number, mainly of sodium and chloride ions, kidneys maintain the normal osmolality of ECF.

(3) **Regulation of pH** : Concentration of hydrogen ions ( $\text{NaH}_2\text{PO}_4$ ) in ECF is to be regulated at a constant value usually expressed as pH (minus log of  $\text{H}^+$ ). The normal pH of ECF is about 7.4. A low pH, i.e. a high  $\text{H}^+$  concentration causes acidosis, while a high pH, i.e. a low  $\text{H}^+$  concentration causes alkalosis. Both of these conditions severely affect cellular metabolism. Several special control systems, therefore, operate in the body to prevent acidosis and alkalosis. These system are called acid-base buffer system. Kidneys play a key role in maintenance and operation of

these systems. Further, the kidneys regulate hydrogen ion concentration in ECF by excreting acidic or basic urine

(4) **Regulation of electrolyte concentrations in ECF** : The kidneys regulate, not only the total concentrations of water and electrolytes in ECF, but also the concentrations of individual electrolytes separately. This regulation is complex and is accomplished by tubular reabsorption and secretion under the control of hypothalamic and adrenal hormones.

(5) **Regulation of RBC-count in blood** : In oxygen deficiency (hypoxia), kidneys secrete an enzyme into the blood. This enzyme reacts with plasma globulin to form erythropoietin. The latter substance stimulates bone marrow to produce more RBCs for enhancing  $\text{O}_2$ -intake in lungs.

(6) **Regulation of renal blood flow** : See (R.A.A.S.).

### Disorders of kidneys

(1) **Pyelonephritis** : It is an inflammation of renal pelvis, calyces and interstitial tissue (*G.pyelos* = pelvis, tub; *nephros* = kidney; *itis* = inflammation). It is due to local bacterial infection. Bacteria reach here via urethra and ureter. Inflammation affects the countercurrent mechanism, and the victim fails to concentrate urine. Symptoms of the disease include pain in the back, and frequent and painful urination.

(2) **Glomerulonephritis** : It is the inflammation of glomeruli. It is caused by injury to the kidney, bacterial toxins, drug reaction, etc. Proteins and R.B.Cs pass into the filtrate.

(3) **Cystitis** : It is the inflammation of urinary bladder (*G.kystis* = bladder, *-itis* = inflammation). It is caused by bacterial infection. Patient has frequent, painful urination, often with burning sensation.

(4) **Uremia** : Uremia is the presence of an excessive amount of urea in the blood. It results from the decreased excretion of urea in the kidney tubules due to bacterial infection (nephritis) or some mechanical obstruction. Urea poisons the cells at high concentration.

(5) **Kidney stone (Renal calculus)** : It is formed by precipitation of uric acid or oxalate. It blocks the kidney tubule. It causes severe pain (renal colic) in the back, spreading down to thighs. The stone may pass into the ureter or urinary bladder and may grow, and cause severe pain of blockage. When in bladder, the patient experiences frequent and painful urination and may pass blood in the urine. Surgery may be needed to remove stone and relieve pain.

(6) **Kidney (Renal) failure (RF)** : Partial or total inability of kidneys to carry on excretory and salt-water regulatory functions is called renal or kidney failure. Kidney failure leads to (i) uremia, i.e., an excess of urea and other nitrogenous wastes in the blood (*G.ouron* = urine, *haima*-blood); (ii) Salt-water imbalance; and (iii) stoppage of erythropoietin secretion.

**Causes** : Many factors can cause kidney failure. Among these are tubular injury, infection, bacterial toxins, glomerulonephritis (inflammation of glomeruli) arterial or venous obstruction, fluid and electrolyte depletion, intrarenal precipitation of calcium and urates, drug reaction, haemorrhage etc.



### Artificial kidney

Artificial kidney called haemodialyser is a machine that is used to filter the blood of a person whose kidneys are damaged. The process is called haemodialysis. It may be defined as the separation of small molecules (crystalloids) from large molecules (colloids) in a solution by interposing a semipermeable membrane between the solution and water (dialyzing solution). It works on the principle of dialysis, i.e. diffusion of small solute molecules through a semipermeable membrane (G. *dia* = through, *lyo* = separate). Haemodialyser is a cellophane tube suspended in a salt-water solution of the same composition as the normal blood plasma, except that no urea is present. Blood of the patient is pumped from one of the arteries into the cellophane tube after cooling it to 0°C and mixing with an anticoagulant (heparin). Pores of the cellophane tube allow urea, uric acid, creatinine, excess salts and excess  $H^+$  ions to diffuse from the blood into the surrounding solution. The blood, thus purified, is warmed to body temperature, checked to ensure that it is isotonic to the patient's blood, and mixed with an antiheparin to restore its normal clotting power. It is then pumped into a vein of the patient. Plasma proteins remain in the blood and the pores of cellophane are too small to permit the passage of their large molecules. The use of artificial kidney involves a good deal of discomfort and a risk of the formation of blood clots. It may cause fever, anaphylaxis, cardiovascular problems and haemorrhage. Kidney transplant is an alternative treatment.

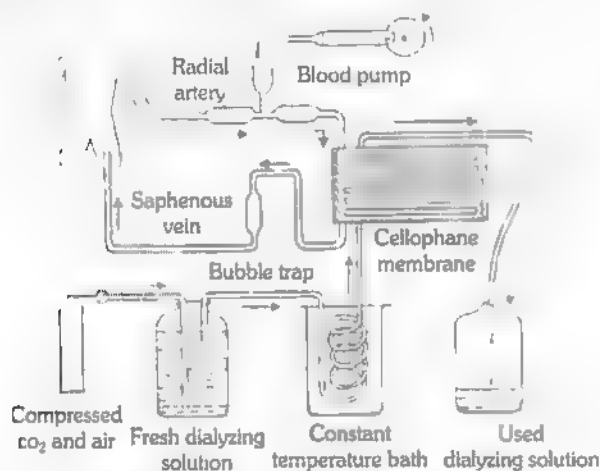


Fig : 5.4-16 Flow of blood through an artificial kidney for haemodialysis

### Kidney (Renal) Transplantation

**Meaning :** Grafting a kidney from a compatible donor to restore kidney functions in a recipient suffering from kidney failure is called renal transplantation.

**History :** First kidney transplant was performed between identical twins in 1954 by Dr. Charles Hufnagel, a Washington surgeon, India's first kidney transplant was done on December 1, 1971 at Christian Medical College, Vellore, Tamilnadu. The recipient was a 35 years old person Shaninughan.

**Eligibility :** All patients with terminal renal failure are considered eligible for kidney transplantation, except those at risk from another life-threatening disease

**Donors :** A living donor can be used in a kidney transplant. It may be in identical twin, a sibling, or a close relative. If the living donors are not available, a cadaveric donor may be used (cadaver is a dead body). Over half of the kidney transplants are from cadavers

**Success rate :** A kidney transplant from an identical twin, called isogeneic graft or isograft, is always successful. A renal transplant from a sibling or a close relative or a cadaver, termed allogeneic graft or homograft, is usually successful with the use of an immunosuppressant that prevents graft rejection by body's immune response. Many renal transplant recipients are known to have retained functional grafts for over 20 years. Earlier, renal transplantation was limited to patients under 55 years. Now, however, with better techniques, kidney grafting has been done in selected patients in the 7<sup>th</sup> decade of life.

**Pretransplant preparation :** It includes haemodialysis to ensure a relatively normal metabolic state, and provision of functional, infection-free lower urinary tract.

**Donor selection and kidney preservation :** A kidney donor should be free of hypertension, diabetes, and malignancy. A living donor is also carefully evaluated for emotional stability, normal bilateral renal function, freedom from other systematic disease, and histocompatibility. Cadaveric kidney is obtained from previously healthy person who sustained brain death but maintained stable cardiovascular and renal function. Following brain death, kidneys are removed as early as possible, flushed with special cooling solutions, such as mannitol and stored in iced solution. Preserved kidneys usually function well if transplanted within 48 hours.

**Recipient-Donor Matching :** Recipient and donor are tested for 3 factors :

(1) **Blood groups :** Recipient's blood group should be compatible with donor's blood group.

(2) **Human leucocyte antigen (HLA) :** It is a genetic marker located on the surface of leucocytes. A person inherits a set of 3 antigens from the mother and three from the father. A higher number of matching antigens increases the chances that the kidney graft will last for a long time.

(3) **Antibodies :** Small samples of recipient's and donor's blood are mixed in a tube. If no reaction occurs, the patient will be able to accept the kidney.

**Transplant procedure :** Transplantation is done under general anaesthesia. Operation takes 3 or 4 hours. Cut is given in the lower abdomen. Donor's kidney is transplanted retroperitoneally in the iliac fossa. Artery and vein of new kidney are connected to the iliac artery and vein of the recipient. Ureter of the new kidney is connected to the urinary bladder of the recipient. Often the new kidney starts producing urine as soon as blood flows through it, but sometimes it may take a few weeks before it starts working. A week's stay in the hospital is necessary to recover from surgery, and longer if there are complications.

The new kidney takes over the work of two failed kidneys. Unless they are causing infection or high blood pressure, the old kidneys are left in place



**Immunosuppression :** Immunosuppression means to depress the immune response of the recipient to graft rejection. Prophylactic immunosuppressive therapy is started just before or at the time of renal transplantation. An ideal immunosuppressant suppress immunity against foreign tissue but maintains immunity against infection and cancer. The drug, named cyclosporin, is such an immunosuppressant. Use of antiserum to human lymphocytes is equally useful. It destroys T-cell mediated immune responses, but spares humoral antibody responses.

### Accessory excretory organs

(1) **Skin :** Many aquatic animals, such as Hydra and starfish, excrete ammonia into the surrounding water by diffusion through the body wall. In land animals, the skin is often not permeable to water. This is an adaptation to prevent loss of body's water. Mammalian skin retains a minor excretory role by way of its sudoriferous, or sweat glands and sebaceous, or oil glands.

(i) **Sweat gland :** Sweat glands pass out sweat. The latter consists of water containing some inorganic salts (chiefly sodium chloride) and traces of urea and lactic acid. It also contains very small amounts of amino acids and glucose.

(ii) **Sebaceous glands :** Oil glands pass out sebum that contains some lipids such as waxes, sterols, other hydrocarbons and fatty acids.

(2) **Lungs :** Carbon dioxide and water are the waste products formed in respiration. Lungs remove the  $\text{CO}_2$  and some water as vapour in the expired air. Lungs have access to abundant oxygen and oxidise foreign substances, thus causing detoxification and also regulate temperature.

(3) **Liver :** Liver changes the decomposed haemoglobin of the worn-out red blood corpuscles into bile pigments, namely, bilirubin and biliverdin. These pigments pass into the alimentary canal with the bile for elimination in the faeces. The liver also excretes cholesterol, steroid hormones, certain vitamins and drugs via bile.

(4) **Large Intestine :** Epithelial cells of the colon transfer some inorganic ions, such as calcium, magnesium and iron, from the blood into the cavity of the colon for removal with the faeces.

(5) **Saliva :** Heavy metals and drugs are excreted in the saliva.

(6) **Gills :** Gills remove  $\text{CO}_2$  in aquatic animals. They also excrete salt in many bony fish.

### Osmoregulation

The regulation of solute movement and hence water movement which follows solutes by osmosis, is known as osmoregulation. Osmosis may be defined as a type of diffusion where the movement of water occurs selectively across a semipermeable membrane. It occurs whenever two solutions, separated by semipermeable membrane (the membrane that allows water molecules to pass but not the solutes) differ in total solute concentrations, or osmolality. The total solute concentration is expressed as molarity or moles of solute per litre of solution. The unit of measurement for osmolality is milliosmole per litre (mosm  $\text{L}^{-1}$ ). If two solutions have the same osmolality, they are said to be isotonic. When two solutions differ in osmolality, the solution with

higher concentration of solute is called hypertonic, while the more dilute solution is called hypotonic. If a semipermeable membrane separates such solutions, the flow of water (osmosis) takes place from a hypotonic solution to a hypertonic one.

**Osmoconformers** are the animals that do not actively control the osmotic condition of their body fluids. They rather change the osmolality of body fluids according to the osmolality of the ambient medium. All marine invertebrates and some freshwater invertebrates are strictly osmoconformer. Osmoconformers show an excellent ability to tolerate a wide range of cellular osmotic environments.

**Osmoregulators**, on the other hand, are the animals that maintain internal osmolality, different from the surrounding medium in which they inhabit. Many aquatic invertebrates are strict or limited osmoregulators. Most vertebrates are strict osmoregulators, i.e. they maintain the composition of the body fluids within a narrow osmotic range. The notable exception, however, are the hagfish (*Myxine* sp., a marine cyclostome fish) and elasmobranch fish (sharks and rays).

Osmoregulators must either eliminate excess water if they are in hypotonic medium or continuously take in water to compensate for water loss if they are in a hypertonic situation. Therefore, osmoregulators have to spend energy to move water in or out and maintain osmotic gradients by manipulating solute concentrations in their body fluids.

## Tips & Tricks

- ✍ Anuria – Failure of kidney to form urine.
- ✍ Oligouria – is less urine output.
- ✍ Cystitis – Inflammation of urinary bladder.
- ✍ Filtration fraction – Ratio between GFR (glomerular filtration rate) and RPF (renal plasma flow).
- ✍ Gout – Painful great toe (arthritis) due to deposition of uric acid.
- ✍ Haematuria – Presence of blood cells in urine.
- ✍ Oedema – Increased volume of interstitial fluid
- ✍ Renal stone – Stone formation in the nephrons of kidney due to accumulation of mainly calcium oxalates some phosphates and uric acid
- ✍ Polyuria – Increased urine volume as in Diabetes insipidus and mellitus.
- ✍ Allantoin and allantonic acid are nitrogenous excretory products formed during embryonic development of amniotes with shelled eggs. Allantoin is also called embryonic waste by allantonic acid is stored in allantois foetal membrane.
- ✍ Bright disease – Characterised by nephritis caused by streptococcal infection.
- ✍ Dysuria – Painful urination.
- ✍ Certain animals are both ammonotelic and ureotelic e.g. *Ascaris*, earthworm, lung fish (African toad), etc.
- ✍ Chordate with flame cells is *Branchiostoma* (also called *Amphioxus*).
- ✍ Nocturia – Increased volume of urine at night.

✎ Abnormal constituent of urine – (i.e. Not present in normal condition).

1. Protein – If protein is present in urine it may be due to infection or injury in kidney. (Mainly albumin is filtered)

2. Blood – Due to infection and injury of kidney blood may appear in urine.

3. Sugar – In diabetes mellitus sugar appear in urine.

4. Bile or bile pigment – In jaundice bile pigment appear in urine

5. Ketone bodies – In starvation and diabetes. Ketone bodies appear in urine.

✎ Diabetes mellitus → Sugar appear in urine due to hyposecretion of insulin.

✎ Diabetes insipidus – Tasteless more urine passing due to hyposecretion of A.D.H.

✎ Diuretics – Diuretic are drugs that increase the rate of urine flow. (Naturally occurring diuretic include caffeine in coffee, tea, and cola soda, which inhibit  $\text{Na}^+$  reabsorption and alcohol in beer, wine and mixed drinks inhibits secretion of ADH).

✎ The most frequent protozoan seen in urine is *Trichomonas vaginalis*, a cause of vaginitis in females and urethritis in males.

✎ Both kidney and ureter are retroperitoneal organ

✎ Urine gives a pungent smell if left for sometime. This smell is of ammonia formed by conversion of urea into ammonia by bacterial action.

✎ A starving person will excrete more urea because during starvation proteins are broken down for energy production.

✎ Cystolith – Stone of the bladder.

✎ Euryhaline are organisms that can tolerate a wide range of salinity, stenohaline are organisms that can live within a narrow range of salinity.

✎ Alkaptonuria – Condition characterised by excretion of large amount of homogentistic acid in urine as a result of incomplete metabolism of amino acids. This causes blackening of urine on standing.



Ordinary Thinking

Objective Questions

### Excretory waste products

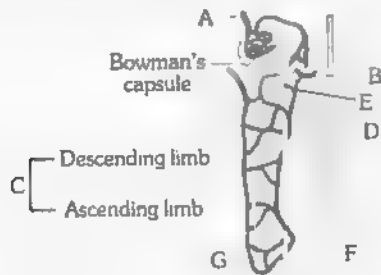
- Kidney crystals are solid clusters of [CBSE PMT 1990]
  - Calcium nitrate and uric acid
  - Phosphate and uric acid
  - Calcium carbonate and uric acid
  - Calcium metabisulphite and uric acid
- Waste products of adenine and guanine (Purines) metabolism are excreted by man as [CBSE PMT 1991; J & K CET 2002]
  - Ammonia
  - Urea
  - Uric acid
  - Allantois
- Uricotelism is a method of conserving [CPMT 1992]
  - $\text{Na}^+$  and  $\text{K}^+$
  - Space
  - Water
  - Energy

- In man, the urea is mainly produced in [CPMT 1992, 93, 2001; Manipal 1995; MP PMT 1998; RPMT 1999; BVP 2002; Kerala CET 2003; Odisha JEE 2005]
  - Liver
  - Kidneys
  - Gall bladder
  - Spleen
- A man takes large amount of protein. He is likely to excrete more amount of [CPMT 2004]
  - Water
  - Glucose
  - Urea and uric acid
  - Salts
- Which one of the following blood vessels in mammals would normally carry the largest amount of urea [MP PMT 1995, 97; BHU 2008; NEET (Phase-I) 2016]
  - Hepatic portal vein
  - Hepatic vein
  - Renal artery
  - Hepatic artery
- Which one of the following is likely to accumulate in a dangerous proportion in the blood of a person whose kidney is not working properly  
Or  
The chief nitrogenous waste in urine of rabbit or terrestrial mammals is [CPMT 1992, 93]
  - Lysine
  - Ammonia
  - Sodium chloride
  - Urea
- The glomerular filtrate consists of [JIPMER 1993]
  - Urea, sodium chloride, fibrinogen and water
  - Glucose, amino acids, urea, oxytocin and calcitonin
  - Both (a) and (b)
  - Urea, glucose, salts and water
- The body cells in cockroach discharge their nitrogenous waste in the haemolymph mainly in the form of [AIPMT 2015]
  - Potassium urate
  - Urea
  - Calcium carbonate
  - Ammonia
- The characteristic that is shared by urea, uric acid and ammonia is/are
  - They are nitrogenous wastes
  - They all need very large amount of water for excretion
  - They are all equally toxic
  - They are produced in the kidneys [NCERT; KCET 2009]
  - A, C and D
  - A and D
  - A, C and B
  - A only
- Which one of the following characteristics is common both in humans and adult frogs [NCERT; CBSE PMT (Mains) 2012]
  - Four-chambered heart
  - Internal fertilisation
  - Nucleated RBCs
  - Ureotelic mode of excretion
- Uric acid is the chief nitrogenous component of the excretory products of [CPMT 2009; CBSE PMT 2009]
  - Man
  - Earthworm
  - Cockroach
  - Frog
- Which of the following nitrogenous substance is highly toxic [NCERT; CPMT 1995; CBSE PMT 2001]  
Or  
If liver from body is removed then which component of blood increases [HPMT 2005]
  - Urea
  - Uric acid
  - Amino acid
  - Ammonia

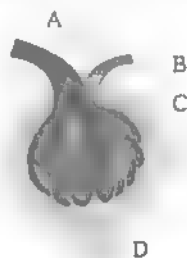
14. Almost all the aquatic animals excrete ammonia as the nitrogenous waste product. Which of the following statement is not in agreement with this situation [KCET 2006]  
 (a) Ammonia is easily soluble in water  
 (b) Ammonia is released from the body in a gaseous state  
 (c) Ammonia is highly toxic and needs to be eliminated as and when formed  
 (d) Ammonia gets converted into a less toxic form called urea
15. The urine is [NCERT; EAMCET 2009]  
 (a) Hypotonic to blood and isotonic in medullary fluid  
 (b) Hypertonic to blood and isotonic to medullary fluid  
 (c) Isotonic to blood and hypotonic to medullary fluid  
 (d) Isotonic to blood and hypertonic to medullary fluid
16. Aquatic reptiles are [CBSE PMT 1999; BHU 2000; CPMT 2003]  
 (a) Ammonotelic (b) Ureotelic over land  
 (c) Ureotelic (d) Ureotelic in water
17. Which of the following is the nitrogenous waste [CPMT 1999; JIPMER 2001]  
 (a) Creatinine (b) Creatine  
 (c) Guanine (d) All the above
18. Choose the wrong statement [Kerala PMT 2012]  
 (a) In ureotelic organisms, ammonia is not a product of metabolism  
 (b) In mammals some amount of urea may be retained in the kidney matrix of ureotelics to maintain osmolarity  
 (c) In fishes, kidneys do not play any significant role in the removal of ammonium ions  
 (d) Urea and uric acid are less toxic than ammonia  
 (e) Ammonia is readily soluble and can diffuse easily
19. Which of the following are uricotelic animals [NCERT; AIIMS 2002; CBSE PMT 2004; CBSE PMT (Pre.) 2011]  
 (a) Rohu and frog (b) Lizard and crow  
 (c) Camel and frog (d) Earthworm and eagle
20. Marine teleosts, undergoing putrefaction, emit sharp characteristic foul odour, which is due to the production of [MP PMT 2002]  
 (a) Trimethylamine (b) Hydrogen sulphide  
 (c) Ammonia (d) Lactic acid
21. Which of the following is a metabolic waste of protein metabolism [NCERT; MP PMT 2002; BHU 2008]  
 (a)  $\text{NH}_3$ , urea and  $\text{CO}_2$   
 (b) Urea, Oxygen and  $\text{N}_2$   
 (c) Urea, ammonia and alanine  
 (d) Urea, ammonia and creatinine
22. Excretion of nitrogenous waste products in semisolid form occur in [NCERT; Kerala CET 2003]  
 (a) Ureotelic animals (b) Ammonotelic animals  
 (c) Uricotelic animals (d) Amniotes
23. Which one is not correct [BHU 2003]  
 (a) Humans – Uricotelic (b) Birds – Uricotelic  
 (c) Lizards – Uricotelic (d) Whale – Ammonotelics
24. Man is [Wardha 2005; CPMT 2010]  
 (a) Ureotelic (b) Uricotelic  
 (c) Ammonotelic (d) Both (b) and (c)
25. Which one of following statements is false [Kerala PMT 2007]  
 (a) Presence of albumin in urine is albuminuria  
 (b) Presence of glucose in urine is glycosuria  
 (c) Presence of ketose sugar in urine is ketonuria  
 (d) Presence of excess urea in blood is uremia  
 (e) Presence of haemoglobin in urine is haemoglobinuria
26. Animal which excrete urea produced during metabolism of amino acids is [AFMC 2004]  
 (a) Ureotelism (b) Uricotelism  
 (c) Ammonotelism (d) Amniotelism
27. Which one of the following options gives the correct categorisation of six animals according to the type of nitrogenous wastes (A,B,C), they give out [NCERT; HP PMT 2005; CBSE PMT (Maine) 2012]
- |     | A-AMMONOTELIC    | B-UREOTELIC               | C-URICOTELIC               |
|-----|------------------|---------------------------|----------------------------|
| (a) | Pigeon, Humans   | Aquatic Amphibia, Lizards | Cockroach, Frog            |
| (b) | Frog, Lizards    | Aquatic Amphibia, Humans  | Cockroach, Pigeon          |
| (c) | Aquatic Amphibia | Frog, Humans              | Pigeon, Lizards, Cockroach |
| (d) | Aquatic Amphibia | Cockroach, Humans         | Frog, Pigeon, Lizards      |
28. The most abundant, harmful and universal waste product of metabolism is [CPMT 2004]  
 (a)  $\text{CO}_2$  (b) Uric acid  
 (c)  $\text{H}_2\text{O}$  (d) None of these
29. The main nitrogenous waste of *Hydra* is [CPMT 2004]  
 (a) Ammonia only (b) Urea only  
 (c) Uric acid only (d) Both (a) and (c)
30. A person is undergoing prolonged fasting. His urine will be found to contain abnormal quantities of [CBSE PMT 2005]  
 (a) Fats (b) Aminoacids  
 (c) Glucose (d) Ketones
31. Urea is directly produced in mammals from [CPMT 2005]  
 (a) Ammonia released by oxidative deamination  
 (b) Oxidative deamination of purines  
 (c) Breakdown of ornithine  
 (d) Breakdown of arginine
32. Nitrogenous waste products are eliminated mainly as [KCET 2007]  
 (a) Urea in tadpole and uric acid in adult frog  
 (b) Urea in adult frog and ammonia in tadpole  
 (c) Urea in tadpole as well as in adult frog  
 (d) Urea in tadpole and ammonia in adult frog

### Excretory organs of different organism

1. See the following diagram and identify A, B, C, D, E, F and G [NCERT]



- (a) A - Afferent arteriole, B - Henle's loop, C - Collecting duct, D - PCT, E - DCT, F - Peritubular capillaries, G - Vasa recta  
(b) A - Afferent arteriole, B - Peritubular capillaries, C - Henle's loop, D - DCT, E - PCT, F - Collecting duct, G - Vasa recta  
(c) A - Efferent arteriole, B - PCT, C - Henle's loop, D - DCT, E - Peritubular capillaries, F - Collecting duct, G - Vasa recta  
(d) A - Afferent arteriole, B - Proximal convoluted tubule, C - Henle's loop, D - Distal convoluted tubule, E - Peritubular capillaries, F - Collecting duct, G - Vasa recta
2. The given diagram represent the Malpighian body. Identify A to D [NCERT]



- (a) A - Afferent arteriole, B - Efferent arteriole, C - Bowman's capsule, D - DCT  
(b) A - Afferent arteriole, B - Efferent arteriole, C - Bowman's capsule, D - Proximal convoluted tubule  
(c) A - Afferent arteriole, B - Efferent arteriole, C - renal corpuscle, D - Proximal convoluted tubule  
(d) A - Efferent arteriole, B - Afferent arteriole, C - Bowman's capsule, D - Proximal convoluted tubule

3. Which of the following does not have an excretory system [Kerala PMT 2011]

- (a) Myxine (b) Carcharodon  
(c) Balanoglossus (d) Asterias  
(e) Catla

4. One of the following does the same work as is done by nephridia in earthworm [CBSE PMT 1996]

- (a) Flame cells in liverfluke (b) Myotomes in fish  
(c) Statocysts in prawn (d) Parotid gland in toad

5. Which one of following correctly explains the function of a specific part of a human nephron

[NCERT; CBSE PMT (Pre.) 2011]

- (a) Afferent arteriole : Carries the blood away from the glomerulus toward renal vein  
(b) Podocytes : Create minute spaces (slit pores) for the filtration of blood into the Bowman's capsule  
(c) Henle's loop : Most reabsorption of the major substance from the glomerular filtrate  
(d) Distal convoluted tubule: Reabsorption of  $K^+$  ions into the surrounding blood capillaries

6. Which of the following is not an excretory organ of vertebrates [Odisha JEE 2010]

- (a) Lungs (b) Skin  
(c) Liver (d) Hepatopancreas

7. The hormone secreted by kidney is [NCERT; MP PMT 2001]

- (a) Gastrin (b) Secretin  
(c) Erythropoietin (d) Aldosterone

8. Select the option which shows correct matching of animal with excretory organs and excretory product

[NEET (Karnataka) 2013]

	Animal	Excretory organs	Excretory product
(a)	Labeo (Rohu)	Nephridial tubes	Ammonia
(b)	Salamander	Kidney	Urea
(c)	Peacock	Kidney	Urea
(d)	Housefly	Renal tubules	Uric acid

9. Forest of nephridia are present in [RPMT 2005]

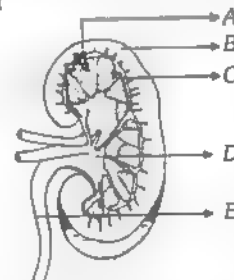
- (a) Pharyngeal region (b) Clitellar region  
(c) Anal region (d) None of these

10. Proboscis gland in *Balanoglossus* is associated with

[Kerala PMT 2011]

- (a) Digestion (b) Respiration  
(c) Circulation (d) Excretion  
(e) Reproduction

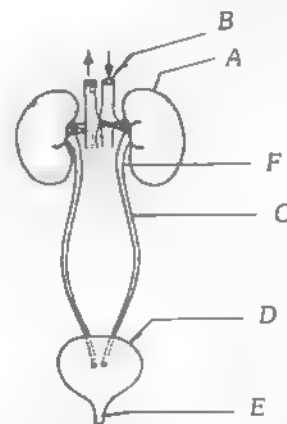
11. Refer the following diagram and identify the parts of a kidney indicated [Kerala PMT 2006]



- (a) A=cortex, B=nephron, C=pelvis, D=medulla, E=ureter  
(b) A=cortex, B=medulla, C=nephron, D=pelvis, E=ureter  
(c) A=nephron, B=cortex, C=medulla, D=ureter, E=pelvis  
(d) A=nephron, B=cortex, C=medulla, D=pelvis, E=ureter  
(e) A=nephron, B=ureter, C=pelvis, D=medulla, E=cortex

12. Which one of the following is correct with reference to haemodialysis [Kerala PMT 2009]  
 (a) Absorbs and resends excess of ions  
 (b) The dialysis unit has a coiled cellophane tube  
 (c) Blood is pumped back through a suitable artery after haemodialysis  
 (d) Anti-heparin is added prior to haemodialysis  
 (e) Nitrogenous wastes are removed by active transport
13. The nephrostomes, in the kidneys, are functional in (AFMC 1999)  
 (a) Rabbit (b) Adult frog  
 (c) Tadpole (d) Cockroach
14. Two examples in which the nitrogenous wastes are excreted from body in the form of uric acid are [NCERT; Pb. PMT 1999; CPMT 2000; AFMC 2004; Kerala PMT 2009]  
 (a) Birds and lizards  
 (b) Mammals and mollusc  
 (c) Insects and bony fishes  
 (d) Frogs and cartilaginous fishes
15. Intestinal excretory organs of *Pheretima* has a function of [CBSE PMT 2000; BHU 2000]  
 (a) Locomotion  
 (b) Respiration  
 (c) Water balance  
 (d) Excretion of nitrogenous waste
16. The region of the nephron found in the renal medulla is [Kerala PMT 2007]  
 (a) Malpighian corpuscle  
 (b) Proximal convoluted tubule  
 (c) Distal convoluted tubule  
 (d) Henle's loop  
 (e) Glomerulus
17. Urinary bladder is absent in [MP PMT 2000; PET (Pharmacy) 2013]  
 (a) Lizards (b) Snakes  
 (c) Crocodiles (d) All the above
18. Which one of the following is associated with osmoregulation in amoeba [RPMT 2000]  
 (a) Endoplasm (b) Mitochondria  
 (c) Contractile vacuole (d) Plasma membrane
19. Excretory system of *Ascaris lumbricoides* is made up of [RPMT 2000]  
 (a) 4 cells (b) Many cells  
 (c) One cell (d) Two cells
20. Which one is the excretory organ in the following [Kerala CET 2003; MP PMT 2013]  
 (a) Archaeocyte (b) Choanocyte  
 (c) Pinacocyte (d) Solenocyte
21. Haemodialysis helps in the patient having [NCERT; BHU 2003]  
 (a) Uremia (b) Anaemia  
 (c) Diabetes (d) Goitre
22. Which pollutant accumulates in liver and kidney [RPMT 2000]  
 (a) Copper (b) Mercury  
 (c) Lead (d) Cadmium
23. Correct order of excretory organs in Cockroach, Earthworm and Rabbit respectively [AFMC 2000; RPMT 2001; BVP 2001; AIIMS 2002; Bihar CECE 2006; Kerala PMT 2007]  
 (a) Skin, malpighi tubules, kidney  
 (b) Malpighi tubules, nephridia, kidney  
 (c) Nephridia, malpighi tubule, kidney  
 (d) Nephridia, kidney, green gland
24. Malpighian tubules remove excretory products from [CPMT 1998; AIIMS 2000]  
 (a) Haemolymph (b) Alimentary canal  
 (c) Both (a) and (b) (d) None of these
25. "Columns of Bertini" in the kidney of mammals are formed as the extension of [CBSE PMT 1991]  
 (a) Medulla into cortex (b) Cortex into medulla  
 (c) Medulla into pelvis (d) Pelvis into ureter
26. Each human kidney has nearly [NCERT; CBSE PMT 1992; CPMT 1992; MP PMT 1996]  
 (a) 10,000 nephrons (b) 50,000 nephrons  
 (c) 1,00,000 nephrons (d) 1 million nephrons
27. The liquid which is collected in the cavity of Bowman's capsule is [MP PMT 2003, 04; WB JEE 2008]  
 (a) Concentrated urine  
 (b) Blood plasma minus blood proteins  
 (c) Glycogen and water  
 (d) Sulphates and water
28. Bowman's capsule and glomerulus together constitute [NCERT]  
 (a) Nothing (b) A nephron  
 (c) Malpighian corpuscle (d) Nephric corpuscle
29. The proximal convoluted tubule has a brush border which is due to [CBSE PMT 1990]  
 (a) Microvilli (b) Minute hairs  
 (c) Endothelium (d) Folded tubes
30. All Bowman's capsules of the kidney are found in [AIIMS 1998; CPMT 1999; JIPMER 2001; Odisha JEE 2011]  
 (a) Cortex (b) Medulla  
 (c) Pelvis (d) None of these
31. The glands which help in absorbing odoriferous substances to stimulate olfactory nerve are [Kerala PMT 2009]  
 (a) Cerumenous glands (b) Meibomian glands  
 (c) Bowman's glands (d) Cowper's glands  
 (e) Bidder's glands
32. Loop of Henle is concerned with [Odisha JEE 2005]  
 (a) Excretory system (b) Reproductive system  
 (c) Nervous system (d) Muscular system
33. Which is common to kidney and skeleton in mammals [MP PMT 2009]  
 (a) Cortex (b) Medulla  
 (c) Pelvis (d) Radius
34. If excess water passes out from the tissue without being restored by the kidneys, the cells would [CBSE PMT 1994]  
 (a) Not be affected at all  
 (b) Shivel and die  
 (c) Burst open and die  
 (d) Take water from the plasma

35. The size of filtration slits of glomerulus [WB JEE 2009]  
 (a) 10 nm (b) 15 nm  
 (c) 20 nm (d) 25 nm
36. Which type of kidneys are found in amphibian (frog) [BCECE 2001; RPMT 2002]  
 (a) Holonephric (b) Mesonephric  
 (c) Pronephric (d) Metanephric
37. Match the excretory organs listed under column I with the animals given under column II. Choose the answer which gives the correct combination of alphabets of the two columns
- | Column I<br>(Excretory organs) |    | Column II<br>(Animals) |  |
|--------------------------------|----|------------------------|--|
| A. Nephridia                   | p. | Hydra                  |  |
| B. Malpighian tubules          | q. | Leech                  |  |
| C. Protonephridia              | r. | Shark                  |  |
| D. Kidneys                     | s. | Round worms            |  |
|                                | t. | Cockroach              |  |
- [KCET 2004]  
 (a) A = q; B = t; C = s; D = r  
 (b) A = s; B = q; C = p; D = t  
 (c) A = t; B = q; C = s; D = r  
 (d) A = q; B = s; C = t; D = p
38. The principal nitrogenous excretory compound in humans is synthesised [CBSE PMT (Pre.) 2010]  
 (a) In the liver, but eliminated mostly through kidneys  
 (b) In kidneys but eliminated mostly through liver  
 (c) In kidneys as well as eliminated by kidneys  
 (d) In liver and also eliminated by the same through bile
39. What is the characteristic of metanephric kidney [MP PMT 2000]  
 (a) Hypotonic urine production  
 (b) Excess secretion of uric acid  
 (c) Loop of Henle  
 (d) Hormone production
40. Integumentary nephridia are also called [DPMT 2004]  
 (a) Enteronephric  
 (b) Exonephric  
 (c) Sometimes enteronephric and sometimes exonephric  
 (d) Both (a) and (b)
41. In the urinogenital organs of rabbit which one of following part is present in male but not in female [CPMT 2005]  
 (a) Urethra (b) Fallopian tube  
 (c) Vagina (d) Vas deferens
42. Loop of Henle is meant for absorption of [MP PMT 1996, 2002, 12; AFMC 1999; BHU 2000]  
**Or**  
 What is removed from the filtrate at loop of Henle [Odisha JEE 2009, 11]  
 (a) Potassium (b) Glucose  
 (c) Water (d)  $CO_2$
43. Juxtaglomerular apparatus is made up of [WB JEE 2012]  
 (a) Juxtaglomerular cell, macula densa and lacin cell  
 (b) Juxtaglomerular cell, Purkinje cell and chief cell  
 (c) Juxtaglomerular cell, lacin cell and myoepithelial cell  
 (d) Juxtaglomerular cell, macula densa and argentaffin cell
44. Which of the following passage way is part of cloaca of vertebrates [DPMT 2004]  
 (a) Rectum (b) The reproductive tract  
 (c) The urinary tract (d) All of these
45. Renin is secreted by [MP PMT 1996, 2001, 02; Odisha JEE 2004; Kerala PMT 2005; MH CET 2015]  
 (a) Cortex (b) Medulla  
 (c) Juxta glomerular cells (d) Podocytes
46. Human kidney has [MP PMT 1993]  
 (a) Ciliated nephron  
 (b) No loop of Henle  
 (c) Mesonephric duct  
 (d) Glomeruli concentrated in the cortex
47. Which of the following is not a function of kidneys [DPMT 1993]  
 (a) Regulation of blood pressure  
 (b) Removal of urea  
 (c) Regulation of acidity of fluids  
 (d) Secretion of antibiotics
48. In the diagram of excretory system of human beings given below, different parts have been indicated by alphabets; choose the answer in which these alphabets have been correctly matched with the parts which they represent [KCET 2000; NEET 2013]



- (a) A = Kidney, B = Abdominal aorta, C = Ureters, D = Urinary bladder, E = Urethra, F = Renal pelvis  
 (b) A = Kidney, B = Abdominal aorta, C = Urethra, D = Urinary bladder, E = Ureters, F = Renal pelvis  
 (c) A = Kidney, B = Renal pelvis, C = Urethra, D = Urinary bladder, E = Ureters, F = Abdominal aorta  
 (d) A = Kidney, B = Abdominal aorta, C = Urethra, D = Urinary bladder, E = Renal pelvis, F = Ureters
49. In rabbit, the urinary bladder opens into [Odisha JEE 2012]  
 (a) Uterus (b) Urethra  
 (c) Ureter (d) Vestibule

50. In which one of the following organisms its excretory organs are correctly stated [NCERT; CBSE PMT (Mains) 2010]  
 (a) Humans - Kidneys, sebaceous glands and tear glands  
 (b) Earthworm - Pharyngeal, integumentary and septal nephridia  
 (c) Cockroach - Malpighian tubules and enteric caeca  
 (d) Frog - Kidneys, skin and buccal epithelium
51. Which one of the following body functions is not performed by kidneys [RPMT 2002]  
 (a) Excretion  
 (b) Osmoregulation  
 (c) Regulation of blood volume  
 (d) Destruction of dead blood corpuscles
52. The basic functional and structural unit of human kidney is [NCERT; DPMT 1993; MP PMT 1995, 2012; CBSE PMT 1997; BHU 1999; RPMT 1999, 2005; AFMC 2001; CPMT 2002; J & K CET 2005; Bihar CECE 2006; Odisha JEE 2012]  
 Or  
 Loop of Henle is found in [CPMT 2001; MP PMT 2010; AMU (Med.) 2012]  
 (a) Nephron (b) Pyramid  
 (c) Nephridia (d) Henle's loop
53. The kidneys of adult mammals are [Bihar MDAT 1995; MP PMT 1999; BHU 2012]  
 (a) Opisthonephros (b) Pronephros  
 (c) Mesonephros (d) Metanephros
54. In which of these animals, antennal gland or green glands functions as excretory organ [CPMT 2001; BHU 2003; Kerala PMT 2008]  
 (a) Human being (b) Cockroach  
 (c) Planaria (d) Prawn  
 (e) Earthworm

### Physiology of excretion

1. Nitrogenous waste in the Malpighian tubule flows into [Odisha JEE 2008]  
 (a) Haemocoel (b) Vacuole  
 (c) Intestine (d) Duodenum
2. The plasma resembles in its composition to the filtrate produced by the glomerulus except the presence of [DPMT 1992]  
 (a) Glucose (b) Chloride  
 (c) Amino acids (d) Proteins
3. What for the ascending limb of Loop of Henle is permeable [MP PMT 1997; JIPMER 2002]  
 (a) Glucose (b)  $\text{NH}_3$   
 (c)  $\text{Na}^+$  (d) Water
4. Water reabsorption in the distal parts of kidney tubules is regulated by [CPMT 2002; MP PMT 1992; DPMT 1992; Pb. PMT 1999; BVP 2000, 01; Odisha JEE 2005; RPMT 2005; AFMC 2010]  
 (a) STH (b) TSH  
 (c) ADH (d) MSH
5. A terrestrial animal must be able to [CBSE PMT 2004]  
 (a) Actively pump salts out through the skin  
 (b) Excrete large amounts of salts in urine  
 (c) Excrete large amounts of water in urine  
 (d) Conserve water
6. Urinary excretion of Na is regulated by [AIIMS 1992]  
 (a) Anterior pituitary (b) Posterior pituitary  
 (c) Adrenal cortex (d) Adrenal medulla
7. Mechanism of uric acid excretion in a nephron is [AIIMS 1998]  
 (a) Osmosis (b) Diffusion  
 (c) Secretion (d) Ultrafiltration
8. The yellow colour of urine of the vertebrates is due to [CBSE PMT 1992; DPMT 1993; BHU 2004; MHCET 2011]  
 (a) Cholesterol (b) Urochrome  
 (c) Uric acid (d) Melanin
9. Which segment of renal tubule is permeable to water but nearly impermeable to salts [CBSE PMT 1992; DPMT 2006; AIIMS 2011; GUJCET 2014]  
 (a) Proximal convoluted tubule  
 (b) Descending limb of Henle's loop  
 (c) Ascending limb of Henle's loop  
 (d) Distal convoluted tubule
10. Sodium, water and phosphate reabsorption is maximum in  
 (a) Loop of Henle (b) Proximal tubule  
 (c) Distal tubule (d) Collecting tubule
11. Human urine is usually acidic because [AIPMT 2015]  
 (a) Excreted plasma proteins are acidic  
 (b) Potassium and sodium exchange generates acidity  
 (c) Hydrogen ions are actively secreted into the filtrate  
 (d) The sodium transporter exchanges one hydrogen ion, for each sodium ion in peritubular capillaries.
12. Which of the following glands does not help in excretion [Odisha JEE 2012]  
 (a) Liver (b) Sweat glands  
 (c) Pancreas (d) Both (a) and (c)
13. At which stage of ornithine cycle arginase is used [AFMC 2006; DUMET 2010]  
 (a) Arginine–Ornithine (b) Ornithine–Citrulline  
 (c) Fumaric acid–Arginine (d) Glycolysis–Urea
14. Which of the following does not favour the formation of large quantities of dilute urine [AIPMT (Cancelled) 2015]  
 (a) Caffeine (b) Renin  
 (c) Atrial-natriuretic factor (d) Alcohol
15. Inflammation of joints due to accumulation of uric acid crystals is called as [NCERT; HP PMT 2005; J & K CET 2008; AFMC 2012; MH CET 2015]  
 (a) Gout (b) Myasthenia gravis  
 (c) Osteoporosis (d) Osteomalacia

16. Protein rich diet brings about relatively no change in one of the following constituents of urine  
(a) Urea (b) Creatinine  
(c) Uric acid (d) Ammonium salts

17. When 2 to 3 drops of benedict's reagent are added to a urine sample and heated gently, it turns yellow. This colour change indicates that [KCET 2011]  
(a) Urine contains 2% glucose  
(b) Urine contains 0.5% glucose  
(c) Urine contains 1.5% glucose  
(d) Urine contains 1% glucose

18. Which of the following cycles in liver is mainly responsible for the synthesis of urea [KCET 1994; BHU 2001; Kerala CET 2003; MP PMT 2003; J & K CET 2010]  
(a) Citruline cycle (b) Kreb's cycle  
(c) Nitrogen cycle (d) Ornithine cycle

19. Proximal convoluted tubule (PCT) is lined with [Kerala PMT 2008]  
(a) Cuboidal epithelium  
(b) Simple brush border epithelium  
(c) Simple cuboidal brush border epithelium  
(d) Simple ciliated brush border epithelium  
(e) Columnar epithelium

20. The part of a nephron which opens into the collecting duct is /are [Kerala PMT 2012]  
(a) DCT (b) DCT and PCT  
(c) Henle's loop (d) Glomerulus  
(e) Bowman's capsule

21. Match the entries in column I with those in column II and choose the correct answer from the following

Column I	Column II
A. Uremia	1. Excess of protein level in urine
B. Hematuria	2. Presence of high ketone bodies in urine
C. Ketonuria	3. Presence of blood cells in urine
D. Glycosuria	4. Presence of glucose in urine
E. Proteinuria	5. Presence of urea in urine

[NCERT; Kerala PMT 2006, 11; DPMT 2007; CPMT 2010]

(a) A - 5, B - 3, C - 2, D - 4, E - 1  
(b) A - 4, B - 5, C - 3, D - 2, E - 1  
(c) A - 5, B - 3, C - 4, D - 2, E - 1  
(d) A - 3, B - 5, C - 2, D - 1, E - 4  
(e) A - 2, B - 1, C - 3, D - 4, E - 5

22. Which of the following disease shows the blockage of kidney tubules and causes severe back pain [GUJCET 2015]  
(a) Renal calculi (b) Kidney failure  
(c) Uremia (d) Nephritis

23. In distal convoluted tubule of the nephrons  
(a) Na reabsorption requires energy  
(b) Secretion of K ions does not require energy  
(c) Water reabsorption requires energy  
(d) Ammonia is secreted

24. The substance which is completely reabsorbed from the filtrate in the renal tubule under normal conditions is [CPMT 1993, 95]  
**Or**  
In nephrons there is complete absorption of [MP PMT 1999]  
(a) Urea (b) Salt  
(c) Glucose (d) Water

25. Effective filtration pressure in glomerulus is caused due to [NCERT; KCET 2011]  
(a) Powerful pumping action of the heart  
(b) Secretion of adrenaline  
(c) Afferent arteriole is slightly larger than efferent arteriole  
(d) Vacuum develops in proximal convoluted tubule and sucks the blood

26. Which of the following function is performed by collecting tubule of kidney [GUJCET 2015]  
(a) In the maintenance of pH and ionic balance of blood by the secretion of  $H^+$  and  $K^+$  ions  
(b) Maintenance of pH of blood and removal of  $Na^+$  and  $K^+$  ions  
(c) Absorption of glucose and ammonia from the blood  
(d) None of above

27. Which of the following causes an increase in sodium reabsorption in the distal convoluted tubule [CBSE PMT 2014]  
(a) Decrease in aldosterone levels  
(b) Decrease in antidiuretic hormone levels  
(c) Increase in aldosterone levels  
(d) Increase in antidiuretic hormone levels

28. A large quantity of fluid is filtered every day by the nephrons in the kidneys. Only about 1% of it is excreted as urine. The remaining 99% of the filtrate [KCET 2009]  
(a) Gets collected in the renal pelvis  
(b) Is lost as sweat  
(c) Is stored in the urinary bladder  
(d) Is reabsorbed into the blood

29. Reabsorption of glucose from the glomerular filtrate in the kidney tubule is carried out by  
**Or**  
Reabsorption in the tubules of nephrons occurs by the process of [AIIMS 2001; AIEEE Pharmacy 2003]  
(a) Active transport (b) Osmosis  
(c) Brownian movement (d) Diffusion

30. Maintenance of body potassium level is primarily by tubular [AMU (Med.) 2010]  
(a) Absorption in PCT  
(b) Secretion in DCT and /or cortical collecting duct  
(c) Absorption in DCT  
(d) Secretion in PCT

31. Which one of the following pair of waste substances is removed from blood in ornithine cycle [CBSE PMT 1996, 2005; AFMC 2000; BHU 2001]  
(a)  $CO_2$  and urea (b) Ammonia and urea  
(c)  $CO_2$  and ammonia (d) Urea and sodium salt



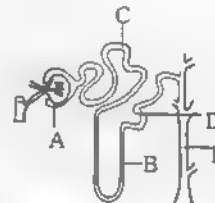
32. The amino acid that acts as a carrier of ammonia from skeletal muscle to liver [DUMET 2010]  
(a) Alanine (b) Methionine  
(c) Arginine (d) Glutamine
33. Which one of the following is correct for a normal human [NCERT; WB JEE 2010; Kerala PMT 2012]  
(a) pH of urine is around 8  
(b) On an average, 25-30 mg of urea is excreted via urine  
(c) Presence of ketone bodies in urine is an indicator of diabetes mellitus  
(d) Glycosuria can be treated with hemodialysis  
(e) Relaxation of smooth muscles of bladder and simultaneous contraction of urethral sphincter causes release of urine
34. A fall in glomerular filtration rate (GFR) activates [NCERT; CBSE PMT (Mains) 2012; KCET 2015]  
(a) Juxta glomerular cells to release renin  
(b) Adrenal cortex to release aldosterone  
(c) Adrenal medulla to release adrenaline  
(d) Posterior pituitary to release vasopressin
35. The end product of ornithine cycle is [AIIMS 1999; MH CET 2000]  
(a) Urea (b) Ammonia  
(c) Uric acid (d) Carbon dioxide
36. The glomerular filtrate contains [NCERT; JIPMER 1993; CPMT 2005; KCET 2009]  
(a) Blood minus cells and proteins  
(b) Blood minus cells  
(c) Blood minus proteins  
(d) Plasma minus cells and proteins
37. The vessel leading blood (containing nitrogenous waste) into the Bowman's capsule is known as [MP PMT 2002]  
(a) Afferent arteriole (b) Efferent arteriole  
(c) Renal artery (d) Renal vein
38. Match the excretory functions of section I with the parts of the excretory system in section II. Choose the correct combinations from among the answers given

	Section I		Section II
(i)	Ultrafiltration	(a)	Henle's loop
(ii)	Concentration of urine	(b)	Ureter
(iii)	Transport of urine	(c)	Urinary bladder
(iv)	Storage of urine	(d)	Malpighian corpuscles
		(e)	Proximal convoluted tubules

[Kerala CET 2005]

- (a) (i) - (d), (ii) - (a), (iii) - (b), (iv) - (c)  
(b) (i) - (d), (ii) - (c), (iii) - (b), (iv) - (a)  
(c) (i) - (e), (ii) - (d), (iii) - (a), (iv) - (c)  
(d) (i) - (e), (ii) - (d), (iii) - (a), (iv) - (b)  
(e) (i) - (d), (ii) - (a), (iii) - (c), (iv) - (b)
39. Glomerular hydrostatic pressure is present in [CPMT 2005]  
(a) Tubule of kidney  
(b) Bowman's capsule  
(c) Glomerulus of uriniferous tubule  
(d) Malpighian tubule

40. The given diagram represents a single nephron from a mammalian kidney. Identify which of the numbered regions is



- I. The site of ultrafiltration  
II. Particularly sensitive to ADH  
III. The main site for the reabsorption of glucose and amino acid  
IV. Largely responsible for the adjustment of blood pH [NCERT]
- (a) I - A, II - B, III - D, IV - E (b) I - A, II - B, III - C, IV - E  
(c) I - A, II - B, III - C, IV - D (d) I - A, II - E, III - C, IV - D
41. Select the correct statement with respect to locomotion in humans [NEET 2013]  
(a) The joint between adjacent vertebrae is a fibrous joint  
(b) A decreased level of progesterone causes osteoporosis in old people  
(c) Accumulation of uric acid crystals in joints causes their inflammation  
(d) The vertebral column has 10 thoracic vertebrae
42. Find the incorrect statement regarding mechanism of urine formation in man [Kerala PMT 2009]  
(a) The glomerular filtration rate is about 125 ml per minute  
(b) The ultrafiltration is opposed by the colloidal osmotic pressure of plasma  
(c) Tubular secretion takes place in the PCT  
(d) Aldosterone induces greater reabsorption of sodium  
(e) The counter current systems contribute in diluting the urine
43. Separation of amino acid into amino and carboxyl group is known as [CPMT 2002; RPMT 2005]

Or

Removal of amino group of amino acid to transform it into keto acid is [DPMT 2004]

- (a) Deamination (b) Excretion  
(c) Amination (d) Egestion
44. The main function of Henle's loop is [BVP 2001; Pb. PMT 2004; Wardha 2005]  
(a) Conservation of water (b) Filtration of blood  
(c) Passage of urine (d) Formation of urine
45. Mark the wrong match from the following [CPMT 2010]  
(a) Bowman's capsule - Glomerular filtration  
(b) DCT - Absorption of glucose  
(c) Henle's loop - Concentration of urine  
(d) PCT - Absorption of  $\text{Na}^+$  and  $\text{K}^+$  ions
46. Active transport is [BHU 1999]  
(a) Formation of ATP  
(b) Against the gradient using ATP  
(c) Along gradient without using ATP  
(d) Against the gradient without using ATP

47. Ultrafiltration takes place in  
(a) Blood capillaries (b) Tissue fluid  
(c) Glomerulus (d) Urinary bladder
48. Reabsorption of useful substances back into the blood from the filtrate in a nephron occurs in [J & K CET 2008]  
Or  
In which part of kidney, Glucose and amino acids are reabsorbed [MP PMT 2003; AFMC 2005; WB JEE 2011]  
Or  
The maximum amount of electrolytes and water (70-80 Percent) from the glomerular filtrate is reabsorbed in which part of the nephron [NCERT; CBSE PMT (Pre.) 2012; WB JEE 2016]  
(a) Proximal convoluted tubule  
(b) Loop of Henle  
(c) Distal convoluted tubule  
(d) Collecting duct
49. Filtration pressure in human kidneys is about  
(a) +15mm Hg (b) +70mm Hg  
(c) +45mm Hg (d) +55 mm Hg
50. Volume of urine is regulated by [Kerala PMT 2004; J & K CET 2010; WB JEE 2010]  
(a) Aldosterone  
(b) Aldosterone, ADH and testosterone  
(c) Aldosterone and ADH  
(d) ADH alone
51. Ornithine an amino acid is found  
(a) As an intermediate of urea synthesis  
(b) As an intermediate of methionine metabolism  
(c) As a major fraction of the connective tissue  
(d) In bile salts
52. Ornithine cycle is related to  
(a) Respiration (b) Nutrition  
(c) Excretion (d) Digestion
53. Substance which is finally excreted in the urine [RPMT 1999; Odisha JEE 2012]  
(a) Amino acid (b) Urea  
(c) Glucose and Glycogen (d) Uric acid
54. The extraction of urine from blood takes place through [CPMT 1992, 93]  
(a) Glomerulus (b) Bowman's capsule  
(c) Henle loop (d) Pelvis
55. Which one of the following statements in regard to the excretion by the human kidneys is correct [CBSE PMT (Pre.) 2010]  
(a) Ascending limb of loop of Henle is impermeable to electrolytes  
(b) Descending limb of Loop of Henle is impermeable to water  
(c) Distal convoluted tubule is incapable of reabsorbing  $\text{HCO}_3^-$   
(d) Nearly 99 per cent of the glomerular filtrate is reabsorbed by the renal tubules
56. In micturition [NCERT; Pb. PMT 1999; BVP 2001; DPMT 2004]  
(a) Urethra relaxes (b) Ureter contracts  
(c) Ureter relaxes (d) Urethra contracts
57. The net pressure gradient that causes the fluid to filter out of the glomeruli into the capsule is [CBSE PMT 2005]  
(a) 50 mm Hg (b) 75 mm Hg  
(c) 20 mm Hg (d) 30 mm Hg
58. Vasopressin is related with [MP PMT 1994]  
(a) Dilution of urine (b) Quick digestion  
(c) Concentration of urine (d) Slow heart beat
59. Which one of the following is not a part of a renal pyramid [NCERT; CBSE PMT (Pre.) 2011]  
(a) Loops of Henle (b) Peritubular capillaries  
(c) Convoluted tubules (d) Collecting ducts
60. Which of the following statement is/are true  
(1) Urine is hypertonic in distal convoluted tubule  
(2) When the urine passes into collecting tubule, it becomes hypotonic  
(3) Urine is isotonic in proximal convoluted tubule  
(4) Urine becomes more and more hypotonic as it passes through Henle's loop [Kerala CET 2005]  
(a) 1 and 4 (b) 1, 2 and 3  
(c) 2 and 3 (d) 3 only  
(e) 1 only
61. In a healthy individual, GFR is about \_\_\_\_\_/min, the volume of the filtrate per day is \_\_\_\_\_ litre, and amount of micturition per day is \_\_\_\_\_ litre [NCERT; CBSE PMT 1992; WB JEE 2011; GUJCET 2014]  
(a) 100 ml., 150 lit., 1.8 lit. (b) 125 ml., 180 lit., 1.5 lit.  
(c) 135 ml., 180 lit., 1.8 lit. (d) 140 ml., 150 lit., 1.8 lit.
62. Blacking of urine when exposed to air a metabolic disorder in human beings. This is due to [Kerala CET 2005]  
(a) Phenylalanine  
(b) Tyrosine  
(c) Valine replacing glutamine  
(d) Homogentistic acid  
(e) Glutamine replacing valine
63. In public urinals, the urine on standing gives a pungent smell, due to [MP PMT 1997]  
Or  
State urine smells like ammonia because of  
(a) Conversion of both urea and uric acid into ammonia  
(b) Conversion of uric acid into ammonia by Ornithine cycle  
(c) Conversion of urea into ammonia by bacteria  
(d) None of the above

64. Which one of the following statement is correct respect to kidney function regulation [NCERT; CBSE PMT (Pre.) 2011]  
 (a) During summer when body loses lot of water by evaporation, the release of ADH is suppressed  
 (b) When someone drinks lot of water, ADH release is suppressed  
 (c) Exposure to cold temperature stimulates ADH release  
 (d) An increase in glomerular blood flow stimulates formation of Angiotensin II
65. At menopause there is rise in urinary excretion of [Odisha JEE 2005]  
 (a) FSH (b) STH  
 (c) LH (d) MSH
66. Prostaglandins affect [RPMT 2000]  
 (a) Blood pressure (b) Defaecation  
 (c) Osmoregulation (d) Oxygen metabolism
67. Which one do not filter out from blood to Bowman's capsule in glomerular ultrafiltration [RPMT 2001]  
 (a) Amino acids (b) Polypeptide  
 (c) Glucose (d) Fatty acids
68. Which one is component of ornithine cycle [MHCET 2003; BHU 2005; CPMT 2009]  
 (a) Ornithine, citrulline and alanine  
 (b) Ornithine, citrulline and arginine  
 (c) Amino acid are not used  
 (d) Ornithine, citrulline and fumaric acid
69. Select the correct statement [Kerala PMT 2011]  
 (a) The juxta medullary nephrons have reduced Henle's loop  
 (b) Vasa recta is well developed in cortical nephrons  
 (c) The PCT and DCT are situated in the medulla of the kidney  
 (d) The glomerulus encloses the Bowman's capsule  
 (e) The ascending limb of the Henle's loop extends as the DCT
70. Ornithine is converted into citrulline by an enzyme  
 (a) Glutamic dehydrogenase  
 (b) Aspartic glutamic transaminase  
 (c) Carbamyl phosphate synthetase  
 (d) Ornithine carbamyl transferase
71. Vasopressin stimulates reabsorption of water and reduction of urine secretion. Hence vasopressin is otherwise called [NCERT; MP PMT 1996; Kerala CET 2005]  
 (a) Sinovial fluid  
 (b) Antidiuretic hormone  
 (c) Neurotransmitter  
 (d) Growth regulating substance  
 (e) None of the above
72. The part of nephron involved in active reabsorption of sodium is [NEET (Phase-II) 2016]  
 (a) Descending limb of Henle's loop  
 (b) Distal convoluted tubule  
 (c) Proximal convoluted tubule  
 (d) Bowman's capsule
73. Which of the following statements on human kidney is false [WB JEE 2016]  
 (a) Renal plasma flow is normally 660 ml/minute  
 (b) Blood flow in the cortex is greater than that in the medulla  
 (c) Reabsorption of ions and water occurs mainly in the distal convoluted tubules  
 (d) The renal blood flow is decreased in dehydration
74. Which of the following statements is correct [NEET 2017]  
 (a) The ascending limb of loop of Henle is impermeable to water  
 (b) The descending limb of loop of Henle is impermeable to water  
 (c) The ascending limb of loop of Henle is permeable to water  
 (d) The descending limb of loop of Henle is permeable to electrolytes

# NCERT

## Exemplar Questions

- The following substances are the excretory products in animals. Choose the least toxic form among them [NCERT]  
 (a) Urea (b) Uric acid  
 (c) Ammonia (d) Carbon dioxide
- Filtration of the blood takes place at [NCERT]  
 (a) PCT (b) DCT  
 (c) Collecting ducts (d) Malpighian body
- Which of the following statements is incorrect [NCERT]  
 (a) ADH – prevents conversion of angiotensinogen in blood to angiotensin  
 (b) Aldosterone – facilitates water reabsorption  
 (c) ANF – enhances sodium reabsorption  
 (d) Renin – causes vasodilation
- A large quantity of one of the following is removed from our body by lungs [NCERT]  
 (a) CO<sub>2</sub> only (b) H<sub>2</sub>O only  
 (c) CO<sub>2</sub> and H<sub>2</sub>O (d) Ammonia
- The pH of human urine is approximately [NCERT]  
 (a) 6.5 (b) 7  
 (c) 6 (d) 7.5
- Different types of excretory structure and animals are given below. Match them appropriately and mark the correct answer from among those given below [NCERT]

Excretory structure/organ	Animals
A. Protonephridia	i. Prawn
B. Nephridia	ii. Cockroach
C. Malpighian tubules	iii. Earthworm
D. Green gland or Antennal gland	iv. Flatworms
(a) (D) i, (C) ii, (B) iii and (A) iv	
(b) (B) i, (C) ii, (A) iii and (D) iv	
(c) (D) i, (C) ii, (A) iii and (B) iv	
(d) (B) i, (C) ii, (B) iii and (A) iv	

7. Which one of the following statements is incorrect [NCERT]  
 (a) Birds and land snails are uricotelic animals  
 (b) Mammals and frogs are ureotelic animals  
 (c) Aquatic amphibians and aquatic insects are ammonotelic animals  
 (d) Birds and reptiles are ureotelic
8. Which of the following pairs is wrong [NCERT]  
 (a) Uricotelic ----- Birds  
 (b) Ureotelic ----- Insects  
 (c) Ammonotelic ----- Tadpole  
 (d) Ureotelic ----- Elephant
9. Which one of the following statements is incorrect [NCERT]  
 (a) The medullary zone of kidney is divided into a few conical masses called medullary pyramids projecting into the calyces  
 (b) Inside the kidney the cortical region extends in between the medullary pyramids as renal pelvis  
 (c) Glomerulus alongwith Bowman's capsule is called the renal corpuscle  
 (d) Renal corpuscle, proximal convoluted tubule (PCT) and distal convoluted tubule (DCT) of the nephron are situated in the cortical region of kidney
10. Match the terms given in Column I with their physiological processes given in Column II and choose the correct answer

**Column I****Column II**

- |                               |   |
|-------------------------------|---|
| A. Proximal convoluted tubule | i. Formation of concentrated urine                  |
| B. Distal convoluted tubule   | ii. Filtration of blood                             |
| C. Henle's loop               | iii. Reabsorption of 70-80% of electrolytes         |
| D. Counter-current mechanism  | iv. Ionic balance                                   |
| E. Renal corpuscle            | v. Maintenance of concentration gradient in medulla |

[NCERT]

**Options**

- (a) A-iii, B-v, C-iv, D-ii, E-i  
 (b) A-iii, B-iv, C-i, D-v, E-ii  
 (c) A-i, B-iii, C-ii, D-v, E-iv  
 (d) A-iii, B-i, C-iv, D-v, E-ii

11. Match the abnormal conditions given in Column A with their explanations given in Column B and choose the correct option

**Column A****Column B**

- |                         |   |
|-------------------------|---|
| A. Glycosuria           | i. Accumulation of uric acid in joints            |
| B. Renal calculi        | ii. Inflammation in glomeruli                     |
| C. Glomerular nephritis | iii. Mass of crystallized salts within the kidney |
| D. Gout                 | iv. presence of glucose in urine                  |

[NCERT]

**Options**

- (a) A-i, B-iii, C-ii, D-iv  
 (b) A-iii, B-ii, C-iv, D-i  
 (c) A-iv, B-iii, C-ii, D-i  
 (d) A-iv, B-ii, C-iii, D-i

12. We can produce a concentrated/dilute urine. This is facilitated by a special mechanism. Identify the mechanism. [NCERT]

- (a) Reabsorption from PCT  
 (b) Reabsorption from collecting duct  
 (c) Reabsorption/Secretion in DCT  
 (d) Counter current mechanism in Henle's loop/Vasa recta
13. Dialysing unit (artificial kidney) contains a fluid which is almost same as plasma except that it has [NCERT]  
 (a) High glucose (b) High urea  
 (c) No urea (d) High uric acid

**Critical Thinking****Objective Questions**

1. A kidney stone is [NCERT; Kerala CET 2003; Manipal 2005]  
 (a) Blockage by fats  
 (b) Deposition of sand in kidney  
 (c) A salt such as oxalate crystallised in pelvis  
 (d) Blockage by proteins
2. What will happen if the stretch receptors of the urinary bladder wall are totally removed [CBSE PMT 2009]  
 (a) Urine will not collect in the bladder  
 (b) Micturition will continue  
 (c) Urine will continue to collect normally in the bladder  
 (d) There will be no micturition
3. Stool of a person contains whitish grey colour due to malfunction of [CBSE PMT 2002]  
 (a) Liver (b) Spleen  
 (c) Kidney (d) Pancreas
4. All of the following animals are ureotelic except [MHCET 2015]  
 (a) Frog (b) Snake  
 (c) Turtle (d) Toad
5. Which of these is not a ketone body [CPMT 2004; WB JEE 2012]  
 (a) Acetoacetic acid (b) Acetone  
 (c) Succinic acid (d) Betahydroxy butyric acid
6. Marine teleost fishes excrete [DPMT 2006]  
 (a) Uric acid (b) Ammonia  
 (c) Urea (d) None of these
7. Which one of the four parts mentioned below does not constitute a part of a single uriniferous tubule [CBSE PMT 1994]  
 (a) Bowman's capsule (b) Distal convoluted tubule  
 (c) Loop of Henle (d) Collecting duct
8. What will happen if one kidney of a person is removed  
 (a) He will still survive and remain normal  
 (b) He will die due to blood poisoning  
 (c) Urea will go on accumulating in blood  
 (d) Urination will stop
9. This is not a nitrogenous waste [AMU (Med.) 2010]  
 (a) Creatinine (b) Purines  
 (c) Allantoin (d) Citrulline

10. Consider the following statements  
 A. Flame cells are excretory structures in flatworms  
 B. Green glands are excretory organs in annelids  
 C. Columns of Bertini are the conical projections of renal pelvis into renal medulla between the renal pyramids  
 [Kerala PMT 2007]  
 (a) A and B correct (b) B and C incorrect  
 (c) A and C correct (d) A, B and C correct  
 (e) A, B and C incorrect
11. In which of the following organisms Malpighian tubule is found  
 [Odisha JEE 2008]  
 (a) Honey bee (b) Frog  
 (c) Ascaris (d) Rabbit
12. Due to insufficient filtration in the Bowman's capsule, all are likely to happen except  
 [AIIMS 1992]  
 (a) Accumulation of fluid in the body  
 (b) Increase in blood pressure  
 (c) Increase in blood urea level  
 (d) Loss of glucose through urine
13. Diuresis is a specific pathological condition which leads to  
 [MP PMT 2001]  
 (a) Increased volume of urine excretion  
 (b) Decreased volume of urine excretion  
 (c) Increased glucose excretion  
 (d) Decreased electrolyte concentration
14. Podocytes are the cells, present in  
 [CPMT 2000; Odisha JEE 2004, 11; Kerala CET 2005]  
 (a) Cortex of nephron  
 (b) Inner wall of Bowman's capsule  
 (c) Outer wall of Bowman's capsule  
 (d) Wall of glomerular capillaries
15. In peritoneal dialysis, .....  
 [KCET 2010]  
 (a) The blood is removed from the body and a natural filter is employed  
 (b) The blood is not removed from the body and a natural filter is used  
 (c) The blood is not removed from the body and an artificial filter is used  
 (d) The blood is removed from the body and an artificial filter is employed
16. Which is not a basic renal function  
 [Odisha JEE 2008]  
 (a) Reabsorption (b) Secretion  
 (c) Perfusion (d) Filtration
17. If Henle's loop were absent from mammalian nephron, which of the following is to be expected  
 [NCERT; CBSE PMT 2003]  
 Or  
 Removal of proximal convoluted tubule from the nephron will result in  
 [AIPMT (Cancelled) 2015]  
 (a) The urine will be more dilute  
 (b) There will be no urine formation  
 (c) There will be hardly any change in the quality and quantity of urine formed  
 (d) The urine will be more concentrated
18. Which of the following is both osmoregulator as well as nitrogenous product  
 [DPMT 2007]  
 (a)  $\text{NH}_3$  (b) Urea  
 (c) Uric acid (d) All of these
19. Which one of the following statements is correct with respect to salt water balance inside the body of living organisms  
 [AIIMS 2005]  
 (a) When water is not available camels do not produce urine but store urea in tissues  
 (b) Salmon fish excretes lot of stored salt through gill membrane when in fresh water  
 (c) *Paramecium* discharges concentrated salt solution by contractile vacuoles  
 (d) The body fluids of fresh water animals are generally hypotonic to surrounding water
20. Fresh water bony fishes maintain water balance by  
 [MHCET 2000; BHU 2002, 04, 12]  
 (a) Excreting a hypotonic urine  
 (b) Excreting salt across their gills  
 (c) Drinking small amount of water  
 (d) Excreting wastes in the form of uric acid

## R Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

- (a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion  
 (b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion  
 (c) If the assertion is true but the reason is false  
 (d) If both the assertion and reason are false  
 (e) If the assertion is false but reason is true

1. Assertion : Ammonia should be eliminated from the body as rapidly as it is formed.

Reason : Ammonia is insoluble in water.

2. Assertion : Urinary bladder and ureters are lined by transitional epithelium.

Reason : Ureters carry the urine to urinary bladder where it is stored temporarily.

3. Assertion : Diabetes insipidus is marked by excessive urination and too much thirst for water.

Reason : Anti-diuretic hormone (ADH) is secreted by the posterior lobe of pituitary gland.

[AIIMS 2004]

4. Assertion : During the physiology of excretion, deamination does not take place in liver cells.

Reason : Deamination is a process to make use of excess of amino acids which cannot be incorporated into the protoplasm.

[AIIMS 2001]

5. Assertion : Phenylketonuria is a recessive hereditary disease caused by the body's failure to oxidize an amino acid phenylalanine to tyrosine, because of a defective enzyme.

Reason : It results in the presence of phenylalanine acid in the urine.

[AIIMS 2000]

6. Assertion : Aquatic mammals like whales and seals are said to be ureotelic animals.  
Reason : It is because of the fact that their main nitrogenous waste product is urea.
7. Assertion : In the descending limb of loop of Henle, the urine is hypertonic, while in ascending limb of loop of Henle, the urine is Hypotonic.  
Reason : Descending limb is impermeable to  $\text{Na}^+$ , while ascending limb is impermeable to  $\text{H}_2\text{O}$ . [AIIMS 1997; KCET 2010]
8. Assertion : Camel can go without water for long periods.  
Reason : Camel stores water in the pouches of their rumen and fat in their hump.
9. Assertion : Renal threshold of glucose is said to be 180 mg per 100 ml.  
Reason : Glucose starts appearing in the urine when its blood level exceed 180 mg per 100 ml of blood
10. Assertion : Earthworms excrete both ammonia and urea.  
Reason : Excretion in earthworm depends on the environment.
11. Assertion : The antidiuretic hormone increases the water permeability of distal convoluted tubule.  
Reason : In absence of ADH, water re-absorption is considerably reduced. [AIIMS 1994]
12. Assertion : In birds and reptiles, main excretory product is the combined form of urine and faeces.  
Reason : Birds and reptiles have no separate chamber for excretion of urine and faeces.
13. Assertion : The glomerular filtrate resembles the protein free plasma in composition and osmotic pressure.  
Reason : The glomerular capillary wall and inner membrane of Bowman's capsule are impermeable to large molecules.
14. Assertion : Kidneys maintain the osmotic concentration of the blood.  
Reason : Kidneys eliminate either hypotonic or hypertonic urine according to the need of the body
15. Assertion : During micturition, urine is prevented from flowing back into the ureters.  
Reason : Urethral sphincters relax during micturition.
16. Assertion : Secreting hypotonic urine is effective in reducing urinary loss of water.  
Reason : Hypotonic urine is more concentrated and higher in osmotic pressure than the blood.
17. Assertion : Urea is a less toxic excretory substance comparatively to uric acid  
Reason : Birds and insects are uricotelic animals. [AIIMS 2010]
18. Assertion : Process of maintaining a constant internal environment is known as homeostasis.  
Reason : Kidneys are excretory and homeostatic organs. [AIIMS 2010]

19. Assertion : The functional unit of excretory organs of lobsters is nephron.  
Reason : The filtration of blood occur in the malpighian body (the glomerulus and Bowman's capsule). [AIIMS 2010]
20. Assertion : Mammals, living in deserts contain more concentrated urine  
Reason : They contain very long loop of Henle in their nephrons. [AIIMS 2010]

## Answers

### Excretory waste products

1	b	2	c	3	c	4	a	5	c
6	b	7	d	8	d	9	a	10	d
11	d	12	c	13	d	14	b	15	b
16	c	17	d	18	a	19	b	20	a
21	d	22	c	23	d	24	a	25	c
26	a	27	c	28	a	29	a	30	d
31	a	32	b						

### Excretory organs of different organism

1	d	2	b	3	d	4	a	5	b
6	d	7	c	8	b	9	b	10	d
11	d	12	b	13	c	14	a	15	d
16	d	17	b	18	c	19	c	20	d
21	a	22	b	23	b	24	a	25	b
26	d	27	b	28	c	29	a	30	a
31	c	32	a	33	c	34	b	35	d
36	b	37	a	38	a	39	c	40	b
41	d	42	c	43	a	44	d	45	c
46	d	47	d	48	a	49	b	50	b
51	d	52	a	53	d	54	d		

### Physiology of excretion

1	c	2	d	3	c	4	c	5	d
6	c	7	d	8	b	9	b	10	b
11	c	12	c	13	a	14	b	15	a
16	d	17	d	18	d	19	c	20	a
21	a	22	a	23	a	24	c	25	c
26	a	27	c	28	d	29	a	30	b
31	c	32	d	33	c	34	a	35	a
36	a	37	a	38	a	39	c	40	d
41	c	42	a	43	a	44	a	45	b
46	b	47	c	48	a	49	a	50	c
51	a	52	c	53	b	54	b	55	d

56	a	57	c	58	c	59	c	60	d
61	b	62	d	63	c	64	b	65	a
66	a	67	b	68	b	69	a	70	d
71	b	72	c	73	c	74	a		

## NCERT Exemplar Questions

1	b	2	d	3	a	4	c	5	c
6	a	7	d	8	b	9	b	10	b
11	c	12	d	13	b				

## Critical Thinking Questions

1	c	2	b	3	a	4	b	5	c
6	d	7	d	8	a	9	d	10	b
11	a	12	d	13	a	14	b	15	b
16	c	17	a	18	b	19	a	20	a

## Assertion and Reason

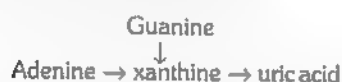
1	c	2	b	3	b	4	e	5	a
6	a	7	a	8	c	9	a	10	a
11	b	12	a	13	a	14	a	15	b
16	d	17	e	18	b	19	d	20	a

# AS

## Answers and Solutions

## Excretory waste products

2. (c) Main sources of uric acid are purines. Purines like adenine and Guanine change into xanthine which changes into uric acid



Nitrogenous waste substances such as Ammonia, urea, or uric acid are produced during protein metabolism according to the species. Small amount of nitrogenous waste substance are also produced during the metabolism of nucleic acids. Ammonia is the most toxic followed by urea and uric acid the latter is the least toxic.

3. (c) Excretion of uric acid is of greater advantage to land animals which have limited access to water. So uricotelism is an adaptation to terrestrial mode of life. Uric acid is expelled in solid state
4. (a) Ornithine cycle is a cyclic process of urea formation which operates in the mitochondria of liver cells and has been studied by kreb's and Henseleit.
5. (c) Because they are the ultimate products of protein catabolism.
6. (b) Since urea formation takes place in liver.
7. (d) Because kidney removes urea.
11. (d) Adult frog and human exhibit ureotelism because their excretory waste product is urea

13. (d) The ammonia is highly toxic because it has high pH. So, it must either be metabolised or expelled immediately out of body, so its concentration remains low in the blood.
16. (c) Ureotelic animals include mainly amphibians and mammals besides its annelids (earthworm) elasmobranch fishes (shark) and aquatic animals are ureotelic.
19. (b) The animals which excrete mainly uric acid are uricotelic. Terrestrial reptiles (lizards and snakes), birds, most insects are uricotelic animals.
20. (a) Marine teleosts form trimethylamine from their ammonia by methylation process which produce foul smell on oxidation.



23. (d) Whale is ureotelic.
27. (c) Those animals who excrete Ammonia are called as Ammonotelic. Eg. Aquatic Amphibia.  
Those animals who excrete Urea are called as Ureotelic. Eg. Frog, Humans  
Those animals who excrete Uric Acid are called as Uricotelic. Eg. Pigeon, Lizards, Cockroach.
28. (a)  $\text{CO}_2$  and  $\text{H}_2\text{O}$  are the end product of complete aerobic oxidation of food through kreb's cycle and electron transport chain (E.T.C.)  $\text{CO}_2$  is most abundant, harmful and universal waste product of metabolism.
29. (a) The main nitrogenous waste of *Hydra* is ammonia. *Hydra* has no organ of excretion, therefore, excretion of waste nitrogenous matter occurs directly by diffusion through all membrane.
32. (b) The main excretory product of frog is urea but excretory product of tadpole larva is ammonia. The urea along with some unnecessary salts and water is collected into the urinary bladder in the form of urine. It will be stored there for some time and is sent out through cloaca. So frog is described as ureotelic animal.

## Excretory organs of different organism

4. (a) Flame cells remove water and nitrogenous wastes in platyhelminthes.
5. (b) Podocytes are specialised squamous epithelial cells in the inner wall of Bowman's capsule. They give rise to foot like processes which form filtration slits for the filtration of blood into the Bowman's capsule.
7. (c) Erythropoietin is secreted from glomerular cells and is concerned with the regulation of normal erythropoiesis.
9. (b) The number of metanephridia varies from 2000-2500 in clitellar segments (but only 200-250 in each of the many other segments).
13. (c) In the tadpoles of frogs, the ciliated funnels, nephrostomes, internally open into the uriniferous tubules.
14. (a) Animals like birds and lizards, which live in dry conditions, have to conserve water for their survival. So, they excrete nitrogenous waste in the form of uric acid.
18. (c) Contractile vacuole found in *Amoeba* acts osmoregulatory processes.

19. (c) *Ascaris* has a 'H'-shaped tubular excretory system. It is supposed to be formed by a huge single excretory renette cell.
20. (d) Solenocytes (flame cells) help in excretion in flatworms (platyhelminthes).
21. (a) Uremia is a condition of high concentration of urea, uric acid in blood etc. Through haemodialysis, waste molecules diffuse into dialysis fluid and the blood is then returned to the patient body.
25. (b) The renal columns of Bertini is the part of cortex continued inside medulla between pyramids.
26. (d) Nephrons are morphological and physiological units of kidney. Man has 10-12 lac ( $10^6$ ) nephrons in each kidney.
28. (c) Malpighian corpuscle (renal corpuscle) consists of Bowman's capsule and glomerulus.
29. (a) The epithelial cells of PCT have brush border due to the presence of abundant microvilli.
40. (b) Integumentary nephridia are also called exonephric nephridia. These are smallest V-shaped and without nephrostome. Integumentary nephridia are scattered in body wall of *Pheretima*.
41. (d) Vas deferens or sperm duct is associated with male reproductive system which arises from cauda epididymis.
45. (c) Renin is an enzyme released by the juxtaglomerular cells into plasma where it converts angiotensinogen into angiotensin I.
50. (b) Earthworm has 3 types of nephridia.
51. (d) Kidney is an excretory organ performing osmoregulation and regulation of blood volume and along with excretion of nitrogenous wastes but never associated with phagocytosis.
52. (a) Nephron is the structural and functional units of kidney, which extract wastes from the blood. It is also called renal tubules or tubule. Each nephron is about 6 cm long and is formed of two parts i.e., Bowman's capsule and body of renal tubule.
53. (d) In amniotes (reptiles, birds and mammals) kidneys are mesonephros in embryonic life but are metanephros in adult stage.
54. (d) In crustaceans, antennary gland or green gland is the chief excretory organ which eliminate ammonia from the animal body.
9. (b) In descending limb of loop of Henle, water is reabsorbed due to increasing osmolality of interstitial fluid. Sodium and other solutes are not reabsorbed here. The filtrate become hypertonic to blood plasma. In ascending limb of loop of Henle, solutes (Na, K, Ca, Mg, Cl) are reabsorbed whereas it is impermeable to water. In distal convoluted tubule, there is active reabsorption of sodium ions from the filtrate under the influence of aldosterone. Collecting duct reabsorb the water and also  $\text{Na}^+$  under the influence of aldosterone.
10. (b) About 65 percent of the glomerular filtrate is normally reabsorbed in the proximal convoluted tubule before reaching the loop of Henle. Glucose, amino acids, vitamins, hormone, sodium, potassium, chlorides, phosphates, bicarbonates, much of water and some urea from the filtrate are absorbed.
14. (b) Renin does not favour the formation of large quantities of dilute urine.
18. (d) The actual process of urea synthesis is a repetitive cyclic sequence of a few reactions occurring continuously in the liver cells. Formation and transformation of three amino acids, namely ornithine, citrulline, and arginine. This cycle is variously referred to as ornithine, arginine or urea cycle.
23. (a) Reabsorption of  $\text{Na}^+$  in the tubules is an active process.
24. (c) Complete reabsorption by active transport takes place for glucose in the PCT.
27. (c) Aldosterone stimulates  $\text{Na}^+$  and water reabsorption in DCT.
29. (a) Reabsorption of glucose from the glomerular filtrate in the kidney tubule is carried out by active transport.
31. (c) Ornithine cycle removes two waste products from the blood in liver. These are  $\text{NH}_3$  and  $\text{CO}_2$ .
35. (a) Ornithine cycle is meant for urea synthesis and ureotelic animals synthesize urea from ammonia in their liver cells.
36. (a) 
$$\text{Glomerular filtrate} = \text{Blood} - (\text{Blood corpuscles} + \text{plasma proteins})$$
$$= \text{Blood plasma} - \text{proteins}$$
43. (a) Deamination is the removal of surplus amino acids or removal of amino group from carboxyl group with the formation of ammonia and keto acid.
44. (a) Loop of henle is a 'U' shaped segment of nephron located in the renal medulla. It helps in conservation of water during counter current mechanism.
46. (b) Active transport is movement across the cell membrane against the gradient with the use of ATP.
47. (c) Ultrafiltration takes place through semipermeable walls of glomerulus and Bowman's capsule.
48. (a) 100% reabsorption of useful substances e.g. glucose takes place at proximal convoluted tubules.
49. (a) Effective filtration pressure in man is + 15 mm Hg. In case of horse and some other mammals it is + 25 mm Hg.
50. (c) Water is reabsorbed in DCT under the influence of ADH secreted by posterior lobe of pituitary gland. This make the filtrate isotonic to blood plasma and aldosterone is associated with the excretion of  $\text{K}^+$  and  $\text{H}^+$  ions some  $\text{Cl}^-$  ions are also reabsorbed.
56. (a) Process of passing out of urine is called micturition. During discharge of urine urethral sphincters relaxes and smooth muscles of bladder wall contract gradually.

### Physiology of excretion

2. (d) Due to large size, protein can't be filtered through the filtration slits. So they are absent in glomerular filtrate.
4. (c) Water is reabsorbed in distal convoluted tubules under the influence of antidiuretic hormone (ADH) secreted by posterior lobe of pituitary gland.
5. (d) Uric acid is least soluble nitrogenous waste and one gm of uric acid needs only 10 ml of water to be expelled out of body. So excretion of uric acid is of greater advantage to land animals which have limited access to water. So uricotelism is an adaptation to terrestrial mode of life.
6. (c) Through mineralocorticoids which is secreted by adrenal cortex.
8. (b) Urine is a transparent, light yellow liquid with a slightly acidic pH (average pH 6.0) the colour of urine is caused by the pigment urochrome, which is a breakdown product of haemoglobin from worn out red blood corpuscles.



58. (c) About 19% water is reabsorbed by the action of the posterior pituitary Anti diuretic hormone (ADH) or vasopressin.
59. (c) In Bowman's capsule PCT and DCT are in renal cortex, whereas, loops of Henle are in medullary pyramids.
60. (d) The filtrate is isotonic to blood plasma (in proximal convoluted tubule) and the filtrate becomes hypertonic to blood plasma (in descending limb of loop of Henle) The filtrate is hypotonic to blood plasma (in ascending limb at loop of Henle) in distal convoluted tubule ADH make the filtrate isotonic to blood plasma.
61. (b) In a healthy adult individual, the glomerular filtration rate is 125 ml/min that is 180 liter/day, but about 99% of the filtrate is reabsorbed producing around 1 to 1.5 liter urine/day.
63. (c) If urine is allowed to stand for some time it smells strongly of ammonia due to bacterial degradation of urea to ammonia.
64. (b) When someone drinks lot of water which is not required by his body, the osmolarity of the blood will decrease. The decrease in osmolarity will inhibit the release of ADH. ADH not released DCT becomes less permeable to water, and excess of water is eliminated.
66. (a) Thromboxanes are synthesized in platelets and upon release cause vasoconstriction and platelet aggregation. Prostaglandins release by blood vessels affect blood pressure.
68. (b) Ornithine cycle is also called urea cycle which takes place in the mitochondria of liver cells. The amino acid arginine and citrulline are formed during formation of urea.
73. (c) Reabsorption of ions and water occurs mainly in PCT

### Critical Thinking Questions

1. (c) Kidney stone is a crystallized chemicals like uric acid, calcium oxalate and calcium phosphate.
3. (a) Since the liver gives colour to the faeces by changing the decomposed haemoglobin into bile pigments - bilirubin and biliverdin.
5. (c) In human and most other mammals, acetyl Co-A formed in the liver during oxidation of fatty acids can enter the citric acid cycle or can be converted to the "ketone bodies" (e.g., Acetone, Acetoacetate and D -  $\beta$  hydroxy butyrate) for export to other tissue.
7. (d) Collecting duct receives the collecting tubules of several nephrons.
8. (a) Other kidney will enlarge in size to perform extra work of missing kidney (compensatory hypertrophy).
12. (d) Insufficient filtration will increase the blood urea level because all the quantity of urea produced by liver would not be filtered through glomerular capsule. Loss of glucose through urine always takes place due to insufficient reabsorption.
14. (b) Podocytes or foot cells are specialised cells of peculiar shape present in the epithelium visceral inner layer of Bowman's capsule, surrounding the glomerulus. They possess foot like process or projections, the pedicels. Hence, called as foot cells
17. (a) The main function of loop of Henle is absorption of water. Hence, in its absence, water is not absorbed and dilute urine is passed out.  
Outer wall of Bowman's capsule is made of squamous cells.
19. (a) Camels produce nearly dry faeces and highly concentrated urine. In the scarcity of water they use only metabolic water and store urea in their body tissue.
20. (a) Fresh water bony fishes take a large amount of water. To get rid of excess water, they pass out hypotonic urine (which is more dilute than blood plasma).

### Assertion and Reason

1. (c) Ammonia is the basic nitrogenous catabolite of proteins. It is highly soluble in water and highly toxic to the animal. So its concentration must be kept very low in the blood. For this reason ammonia should be eliminated as rapidly from the body as it is formed. A large volume of water is needed by the animals to dissolve ammonia and eliminate it from the body. So, its elimination in urine involves considerable loss of water from the body.
2. (b) Urinary bladder and ureters of excretory system are lined by transitional epithelium because it is a stretchable epithelium, hence the urinary bladder and ureters may be considerably stretched without getting torn when they are filled with urine. Ureters are thin muscular tubes which emerge from the hilum of each kidney. Urine enters the ureters from the renal pelvis and is conducted along the ureters by peristaltic waves on their walls. Ureters from both the kidneys finally open into urinary bladder which is a hollow muscular sac. In this way urine from both the kidneys is drained into the urinary bladder which stores it temporarily.
3. (b) Antidiuretic hormone (ADH) or vasopressin is secreted from posterior pituitary gland. It is released in response to a fall in the water content of blood plasma and lead to an increase in the permeability to water of the distal and collecting tubules of the nephron. Deficiency or hyposecretion of ADH results in diabetes insipidus. Diabetes insipidus is characterised by micturating dilute urine several times a day which results in excessive thirst (polydipsia) and dehydration.
4. (e) Deamination is to make use of excess of amino acid which cannot be incorporated into the protoplasm by removal or protein or amino acids or amino group from carboxyl group with the formation of ammonia and keto acid.
5. (a) Phenylketonuria results when there is a deficiency of liver enzyme phenyl alanine hydroxylase that converts phenyl alanine into tyrosine. It results with a high level of phenyl alanine in blood, tissue fluids and urine.
6. (a) Ureotelism is defined as the urinary elimination of nitrogen mainly as urea. Aquatic mammals like whales and seals are said to be ureotelic animals because their major nitrogenous waste product is urea. As a matter of fact, ammonia is the basic nitrogenous catabolite of protein but since ammonia is highly toxic to the animals, therefore, its concentration must be kept very low in the blood.
7. (a) Descending limb is permeable to water but not to  $\text{Na}^+$ . Consequently water moves out into interstitium and concentration of  $\text{Na}^+$  in tubular filtrate rises making the filtrate hypertonic. Ascending loop is impermeable to water but permeable to  $\text{Na}^+$  and makes the filtrate hypotonic.
8. (c) Camels have the ability to withstand water deprivation for long periods. But they do not store any water in the pouches of their rumen. The fat of hump is not particularly useful as a source of water because respiration must be enhanced to oxidise fat for producing water and this enhances respiratory loss of moisture. They reduce urinary water loss by secreting small volume of the urine much more hypertonic than the human urine. They lose far less water in the sweat, because they sweat only when their body temperature rises by as much as  $60^\circ\text{C}$ , compared to all other mammals. These factors are mainly responsible for the camel's ability to go without water for long periods.

9. (a) Renal threshold of a substance is its highest concentration in the blood, upto which it is totally reabsorbed from the glomerular filtrate. Renal threshold of glucose is about 180 mg per 100 ml. It is totally reabsorbed and does not appear in the urine so long as its blood level does not exceed 180 mg. But when its blood level exceeds 180 mg, some of the filtered glucose is left unabsorbed in the tubules and consequently appears in the urine. Some substances which are either totally reabsorbed actively or most of their amounts are reabsorbed actively are called high threshold substances. High threshold substances are excreted in the urine only when their blood concentration is considerably high, for example glucose and amino acids.
10. (a) Earthworms excrete ammonia when sufficient water is available, because a large volume of water is needed by the animal to dissolve ammonia and eliminate it from the body. Whereas in drier environment the animal eliminates urea as it requires only considerable amount of water for the excretion of urea because urea is very soluble in water.
11. (b) ADH is secreted by pituitary gland. It increases the water permeability of distal convoluted tubules and collecting tubules, hence, plays a significant role in water re-absorption. The absence of ADH will reduce water reabsorption which may lead to water diuresis or diabetes insipidus.
12. (a) In birds and reptiles, ureters and the rectum open into a common sac called the cloaca (as there is no chamber for urine and faeces) for these two which stores both, and reabsorbs water from them and ultimately excretes these white and brownish black material along with aqueous fluid.
13. (a) Glomerular filtrate is the protein free fluid which is filtered from the blood of glomerular capillaries to the lumen of the Bowman's capsule. This process is called glomerular filtration. About one-fifth of the total volume of plasma flowing through the kidneys is filtered out as the glomerular filtrate. The filtration occurs across the membrane made of the glomerular capillary wall and the inner membrane of the Bowman's capsule. The pores of this following membrane are impermeable to large molecules or particles. Large particles like blood cells and protein macromolecules do not normally enter into the glomerular filtrate. But smaller molecules like glucose, urea, creatinine, amino acids and mineral salts are filtered into the Bowman's capsule in concentrations more or less similar to their respective concentrations in the plasma. The filtrate therefore almost resembles the protein free plasma in composition and osmotic pressure.
14. (a) Kidneys play an essential role in maintaining the concentration and osmotic pressure (osmoconcentration) of blood. When water intake of an animal is very high, the urine excreted has to be hypotonic i.e., dilute and lower in osmotic pressure than their blood in order to remove the excess of water contrary to this, when there is a threat of excessive water loss from the body, the urine needs to be hypertonic more concentrated and higher in osmotic pressure than their blood, to reduce the loss of water with urine. In this way, the osmotic concentration of the blood is maintained.
15. (b) The act of voiding the urine is called micturition. Besides functioning as a temporary reservoir of urine, the urinary bladder also evacuates the urine by the process of micturition at suitable intervals. When enough urine has accumulated in the bladder to distend the bladder and raise its pressure sufficiently, a spontaneous nervous activity (reflex) is initiated; this causes the smooth muscles on the bladder wall to contract and the urethral sphincters, which guard the urethra, to relax. Urine consequently flows from the bladder through the urethra to the exterior. But it is prevented from flowing back into the ureters, because the terminal part of each ureter passes obliquely through the bladder wall and is consequently closed due to compression by the contracting bladder muscles.
16. (d) When there is a threat of excessive water loss from the body of the animal, then the urine excreted needs to be hypertonic and not hypotonic because excessive water loss from the body poses the threat of a rise in osmoconcentration of the blood. Since hypertonic urine is more concentrated and higher osmotic pressure than the blood, therefore it helps in reducing the loss of water with urine. Mammals and birds can excrete hypertonic urine which is more concentrated than their blood. For this, an isotonic glomerular filtrate is first filtered into the Bowman's capsules of nephrons in kidneys. The tubules of nephrons then reabsorb a large volume of water from the glomerular filtrate not accompanied by the reabsorption of proportionate amounts of solutes. This leaves the urine more concentrated than the blood which is very effective in reducing the urinary loss of water.
17. (e) Urea is more toxic than uric acid and less toxic to ammonia  
Ammonia > Urea > Uric acid  
Urea formation takes place in kidneys.  
Birds and insects are uricotelic animals.
18. (b) Walter Cannon (1932) was introduced the term homeostasis (homeios = same; stasis = standing). Homeostasis maintains the stability of the cell environment and this way provides the organism with a degree of independence of the environment; in order to achieve stability. Mammals have two kidneys which perform excretory function and maintain urea level in blood.
19. (d) Nephron is the principal functional unit of the kidney of vertebrates. Its number reaches to one million in each kidney  
Filtration of blood occurs in Malpighian body, later is composed of a tuft of capillaries called the glomerulus together with the cupped end of the renal tubules, known as Bowman's capsule.
20. (a) Functional unit of kidney is known as nephron. Later contains a tubular region between proximal and distal convoluted tubule, the loop of Henle. The length of loop of Henle is proportional to the concentration of urine. The mammals (chordates) living in desert contain longer loop of Henle in their nephrons. Due to this, these animals contain more concentrated urine.

## Excretory Products and their Elimination

## SET Self Evaluation Test

1. Column I contains some terms and Column II contains their meanings. Match them properly and choose the right answer

Column I		Column II	
A.	Glycogenesis	1.	Conversion of glycogen to glucose
B.	Glycosuria	2.	Conversion of glucose to glycogen
C.	Gluconeogenesis	3.	Excretion of glucose in urine
D.	Glycogenolysis	4.	Conversion of noncarbohydrate sources to glucose
		5.	Conversion of glucose to starch

[KCET 2011; Odisha JEE 2012]

- (a) A-1, B-2, C-3, D-4 (b) A-2, B-3, C-4, D-1  
(c) A-2, B-1, C-3, D-4 (d) A-1, B-5, C-2, D-4

2. A condition of failure of kidney to form urine is called

[CBSE PMT 1998; BVP 2001]

- (a) Deamination (b) Entropy  
(c) Anuria (d) None of these

3. Marcello Malpighi after whom malpighian corpuscles are named was born in

[HP PMT 2005]

- (a) Germany (b) Italy  
(c) Australia (d) Austria

4. The average quantity of urea excreted in urine by man per day is

[NCERT; Kerala PMT 2010; MP PMT 2011]

- (a) 1-5 gm (b) 25-30 gm  
(c) 1-1.5 litres (d) 80 gm  
(e) 100-500 mg

5. Many freshwater animals cannot live for long in sea water and *vice versa* mainly because of the

[Kerala PMT 2010]

- (a) Change in N levels  
(b) Change in the levels of thermal tolerance  
(c) Variations in light intensity  
(d) Osmotic problems  
(e) Spectral quality of solar radiation

6. The conversion of  $\text{NH}_3$  into urea occurs in

[NCERT; CPMT 1998; RPMT 1995, MP PMT 2009]

Or

Transamination process takes place in

[CPMT 1995]

- (a) Intestine (b) Spleen  
(c) Kidney (d) Liver

7. The absorption of  $\text{Na}^+$  and secretion of  $\text{K}^+$  by the nephron is under the control of hormone

- (a) ADH (b) Corticosterone  
(c) Aldosterone (d) Progesterone

8. Filtration takes place in

[MP PMT 1998]

- (a) Malpighian corpuscles (b) Bowman's capsule  
(c) Glomerulus (d) Collecting tubule

9. Angiotensinogen is converted into angiotensin by

[AIIMS 1999]

- (a) Parathyroid hormone (b) Androgen  
(c) Aldosterone (d) Renin

10. A person who is starving, that is not having food and is surviving only on water will have

[CBSE PMT 2007]

- (a) More urea in his blood (b) Less urea in his urine  
(c) Less fats in his urine (d) More glucose in his blood

## AS Answers and Solutions

1	b	2	c	3	b	4	b	5	d
6	d	7	c	8	a	9	d	10	b

2. (c) The condition in which kidney failed to form urine is called anuria.

3. (b) The composite structure of Bowman's capsule and glomerulus is known as malpighian body or malpighian corpuscles after the Italian microscopist Marcello Malpighi.

6. (d) The process of urea formation operates in mitochondria of liver cells. Transamination means transference of an amino group ( $-\text{NH}_2$ ) from an amino acid to another substance. This process is essential for growth and in case of vertebrates it takes place in liver.

8. (a) Filtration takes place through semipermeable walls of glomerulus and Bowman's capsule. Glomerulus and Bowman's capsule are collectively called malpighian corpuscle.

9. (d) Renin change plasma protein, called angiotensinogen to a peptide called angiotensin.

10. (b) As urea is the main excretory product of mammals and if the person is starving, he will have less urea in his urine.



## Chapter

# 5.5

## Locomotion and Movement

The study of bone structure and treatment of bone disorders is called osteology. The specialized branch of medicine that deals with preservation and restoration of skeletal system, joints is called orthopedics. Bones are made up of a protein called ossein and cartilage are made of a protein called chondrin. Hence study of bones is called osteology and study of cartilage is called chondrology. Body of animals (vertebrates) is supported by skeleton

### Skeleton

The hardened tissues of the body together form the skeleton (sclero = hard). Skeleton of invertebrates is most often secreted on the surface, forming a lifeless or dead exoskeleton. Whereas skeleton of vertebrates develops most often underneath the surface forming a living or growing endoskeleton. Three types of skeletons develop in vertebrates :

(1) **Epidermal/Horny exoskeleton** : These include hard and horny keratinized derivatives of epidermal layer of skin, such as claws, most reptilian's scales, bird feathers and mammalian hairs, horns, nails and hoofs, etc. All living amphibians lack an exoskeleton.

(2) **Dermal/Bony skeleton** : Dermal bony skeleton is derived from the dermis of skin. It includes bony scales and plates or scutes (*osteoderms*), finrays and antlers of fishes, some reptiles (crocodiles, turtles and tortoises) and mammals. In fishes, dermal scales become exposed due to wearing out of epidermis, and form exoskeleton.

(3) **Endoskeleton** : Greater part of vertebrate skeleton lies more deeply, forming the endoskeleton. It develops from mesenchyme. Endoskeleton is formed by bones in vertebrates. Skeleton in different animals are as follows –

#### Invertebrate –

(i) Protozoa – No skeleton.

(ii) Porifera – Calcareous spicules + silicious spicules + spongin fibre in mesenchyme.

Spicules in porifera represent endoskeleton.

(iii) Coelenterata – Calcareous (corals) and chitinous (perisarc).

(iv) Helminth – No skeleton, cuticle? present.

(v) Annelida – No skeleton, cuticle present.

In earthworm and ascaris hydrostatic skeleton is found that is fluid is filled in coelom and form turgid skeleton.

(vi) Arthropoda – Dead chitinous exoskeleton, shed at intervals, called ecdysis or moulting. Cuticle made up of non chitinous outer epicuticle and chitinous, inner endocuticle.

(vii) Mollusca – Calcareous shell, may be external or internal or absent.

(viii) Echinodermata – Dermal calcareous plates are present.

(ix) Hemichordates – Endoskeleton in form of proboscis skeleton, pygochord.

In vertebrates exoskeleton may be epidermal or dermal.

**Vertebrates** : In vertebrates dermal skeleton is formed by bones. Bone is the connective tissue with intercellular spaces filled with ossein matrix composed of 25% water, 25% protein fibers, 50% mineral salts. The inner most region is full of bone marrow having various types of cells. In mammals the bone is full of haversian canals. The bones are of following types –

(i) **Cartilage bones** : The bones which are formed by the ossification of preexisting cartilage are called cartilage bones or replacing bones. e.g., vertebra, Girdles, limb bones, basioccipital, supraoccipital, sphenoid, Incus, malleus, stapes

(ii) **Membrane or dermal bones** : The bones which are formed by independent ossification in connective tissue are called dermal, membrane or investing bones. e.g., Ribs, sternum, clavicle, Nasal, vomer, palatine, maxilla

(iii) **Sesamoid bones** : Ossification takes place on ligament e.g., cotyloid bone of Rabbit and tendons e.g., Patella, Pisiform.

(iv) **Pneumatic bones** : Bones with hollow spaces containing air e.g., bones of bird, frontal, sphenoid, ethmoid, maxilla of human.

(v) **Irregular bones** : Vertebrae are irregular bone.

(vi) **Flat bones** : Cranial bone, scapula, Ribs.

(vii) **Short bones** : Carpals and tarsals.

**Functions of endoskeleton** : Chief function of vertebrate endoskeleton can be enumerated as follows

(i) To provide physical support to body by forming a firm and rigid internal framework.

(ii) To give definite body shape and form.

(iii) To protect delicate internal organs like brain, heart, lungs etc.

(iv) To permit growth of huge body size (whale, elephant, extinct dinosaurs), since it is living and growing.

(v) To provide surface for attachment of muscles.

(vi) To serve as levers on which muscles can act.

(vii) To manufacture blood corpuscles in bone marrow.

(viii) To help in breathing (tracheal rings, ribs).

### Endoskeleton of vertebrates

(1) Axial endoskeleton : (Skull + Vertebral column + Sternum + Ribs)

(2) Appendicular endoskeleton : (Girdle + Limb bones)

#### SKELETON

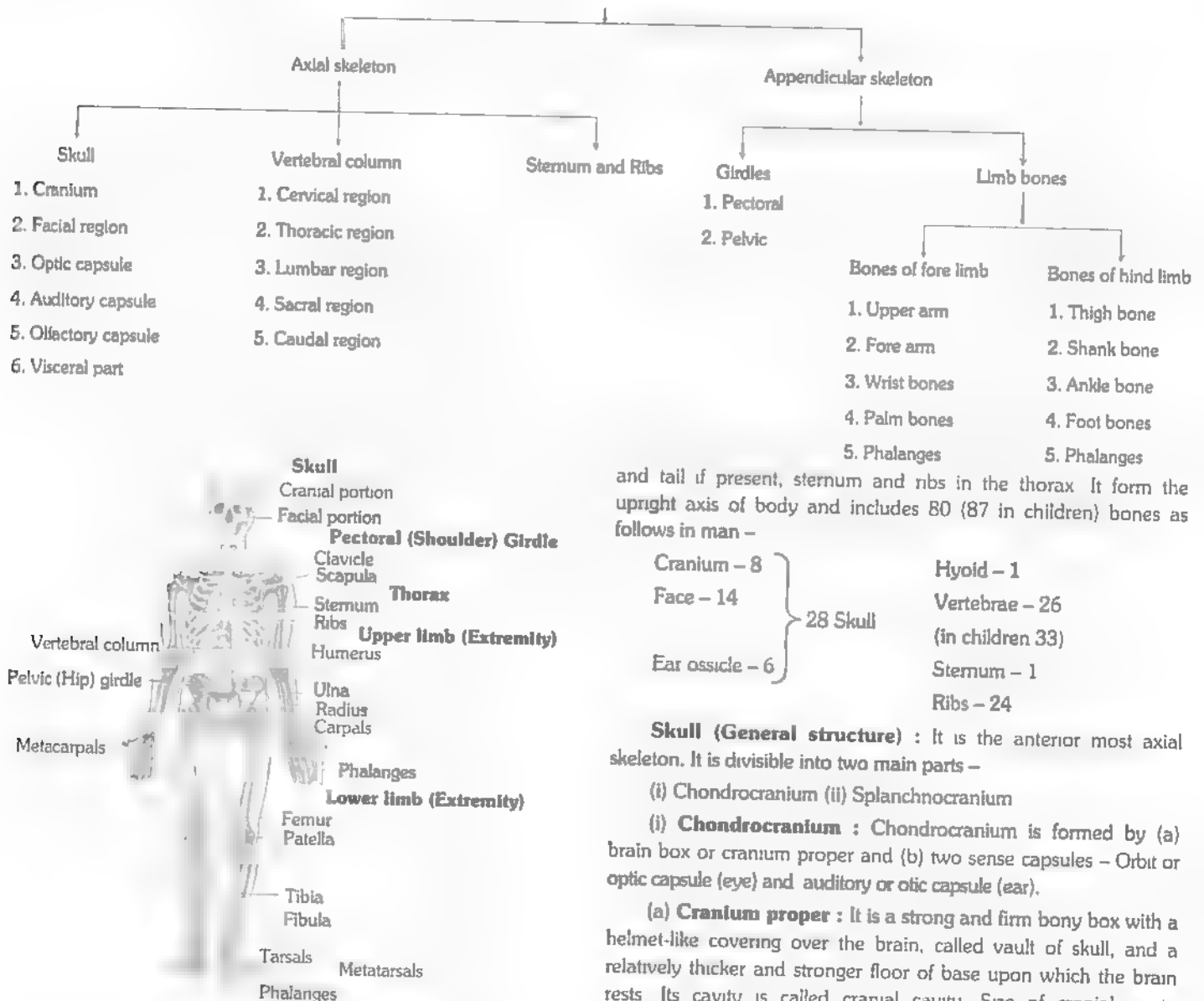


Fig : 5.5-1 Divisions of skeletal system

#### Axial skeleton (Human)

It occupies the body's main longitudinal axis. It includes four structure : skull in the head, vertebral column in the neck, trunk

❑ **Occipital zone** : Occipital zone has one supra-occipital bone on dorsal side, one basioccipital on ventral side and two exoccipital on both lateral side of foramen magnum. Foramen magnum is present in ventral side of skull, which fits on 1st atlas vertebra. Two occipital condyles forming dicondylic skull at the junction of supra and exo-occipital.

❑ **Parietal zone** : In the dorsal side of cranium parietal zone has three bone, that is two parietal, one inter parietal and ventral side of cranium has 3 bone i.e. one basisphenoid with pituitary foramen and two alisphenoid bone.

❑ **Frontal** : Frontal part of cranium has two frontal bone in dorsal side, each frontal bone has one process called supra orbital process of frontal. Two orbitosphenoid, one presphenoid bone in ventral side

❑ **Ethmoidal** : Ethmoidal part has one circular plate called cribriformplate. That plate is having two perforation for exit of I cranial nerve

(b) **Sense capsule** : Chondrocranium contains two sense capsule.

❑ Optic or orbital capsule

❑ Otic or auditory capsule

**Optic capsule** : One pair of optic or orbital capsule is present in frontal zone of chondrocranium. It is made up of 7 pairs of bones which are –

I – Pre frontal II – Post frontal III – Anterior orbital

IV – Posterior orbital V – Infra orbital VI – Supra orbital

VII – Lacrimal

In frog optic capsules are absent but in place of optic capsule eye-orbit are present in same position. In between two eye capsule, a separating bone is present in mammals only. This separating bone is called inter-orbital septum. This septum is absent in frog between two eye orbits

**Auditory or Otic capsule** : Auditory capsule is located between occipital and parietal zone. It has two parts – Tympanic bulla and External auditory meatus. Auditory capsule in vertebrates is formed by 5 pairs of otic bones.

(I) Preotic (II) Epiotic (III) Opisthotic (IV) Sphaenotic  
(V) Pterotic

Out of these 5 pairs only 1 pair i.e. preotic participate in formation of auditory capsule of frog i.e. amphibian. In mammals e.g., rabbit I, II & III pair fuse to form a fusion bone called periotic, which forms the auditory capsule. In reptiles and birds (aves) all 5 pairs bone together constitute auditory capsule. Membranous labyrinth is enclosed in the preotic and tympanic bulla. Auditory capsule has two distinct part – Outer spongy part called petrous part and inner bony part called mastoid part.

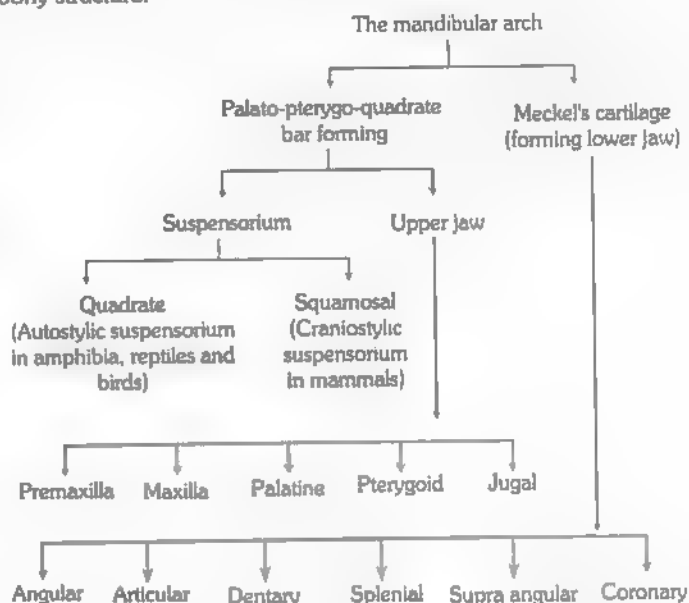
(II) **Splanchnocranium** : It is also known as facial. It includes following parts –

❑ **Visceral skeleton** : Visceral skeleton is formed by pairs of visceral arches which are –

**Mandibular arch (I pair of visceral arch)** : It is made of two arches one is upper forming upper jaw and second is lower called lower jaw. In tadpole stage upper jaw i.e. upper part of mandibular arch is formed by the fusion of three cartilage called

palatine, pterygoid and quadrate. These all fused to form palato-ptyergoquadrate.

Lower jaw or II part of mandibular arch is cartilagenous initially and is called Meckel's cartilage which soon changes into bony structure.



(a) **Upper jaw** : The upper jaw is made of 14 bones i.e. 7 pairs of bones which are – Premaxilla, Maxilla, Jugal, Squamosal, Pterygoid, Palatine, Quadrate.

Out of these 7 pairs of bones only quadrate are not visible because they constitute II ear ossicle i.e. – incus. In man the nasal cavity is separated from the buccal cavity by bone called palatine complex. Palate of birds is identical in animal kingdom, which is used for birds classification.

#### Process of upper jaw

**Premaxilla** : Nasal process on dorsal side which are covered by Nasal; Palatine process of premaxilla.

**Maxilla** : Nasal process of maxilla; Palatine process of maxilla; Zygomatic process of maxilla.

**Squamosal** : Only zygomatic process of squamosal.

(b) **Lower jaw** : It is composed of 6 pairs of bone i.e. 12 bones maximum. These are articular, angular, splénial, dentary, coronoid and supra angular.

In frog out of 6 pairs only 4 pairs of bones are present. Only 3 pairs form lower jaw and one pair forms I ear ossicle i.e. columella auris. Remaining 3 pairs i.e. Angular, splénial and dentary combine to form lower jaw of frog. In mammals only one pair of bones are present of which only one pair i.e. dentary forms lower jaw.

Upper jaw in vertebrates is completely ossified with skull but lower jaw is always free from chondrocranium and hangs downwardly. A bone hangs lower jaw from upper jaw. This bone is called suspensorium. A skull in which suspensorium is formed by quadrate is called autostylic skull e.g., frog skull. A skull in which suspensorium is formed by squamosal is called craniostylic skull e.g., rabbit skull (all mammal).

**Hyoid arch (II pair of visceral arch)** : It is also one pair which is called Hyoid proper and Hyomandibular.

(a) **Hyoid proper** : It is a horse-shoe shaped bone in our neck between lower jaw and sound box or larynx. It is not articulate to any bone but is simply suspended from temporal bones by means of ligament. It consists of an elliptical main part or body and two processes on each side of body, called greater and lesser cornua. It supports our tongue and provides insertion to some tongue muscles. In collaboration with branchial arches forms hyoid apparatus in terrestrial vertebrates. It is absent in fishes because branchial arches form gill rakers which support gills.

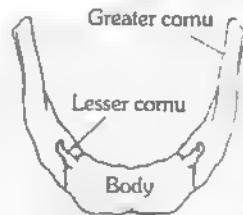


Fig. 5.5-2 : Human hyoid bone viewed from above

(b) **Hyomandibular** : It is second part of hyoid arch which constitutes ear ossicles in vertebrate. In frog hyomandibular forms stapedial plate which is II ear ossicle which is dot or lid like bone. In rabbit hyomandibular forms stapes which is III ear ossicle. That is stirrup like bone.

Table : 5.5-1 Ear ossicles

I	II	III
Malleus	Incus	Stapes
Articular	Quadrate	Hyomandibular
Hammer	Anvil	Stirrup

#### Branchial arches (III to VII pair of Visceral arches) :

These are five pairs, which constitute III to VII pair of visceral arches. These constitute gill raker in fishes but terrestrial animals then form hyoid apparatus in collaboration with hyoid proper. Five pairs of branchial arches are as follows –

- (a) III pair ceratohyle. (b) IV pair i.e. is epihyal.
- (c) V pair i.e. is stylohyal. (d) VI pair i.e. tympanohyal.
- (e) VII pair i.e. thyrohyal.

#### Skull of man

In man however the skull remain erect at top of vertebral column because of perfectly erect posture of body it is divisible into the large and hollow cranium and the facial region together protects and support some useful organ for vision, taste, smell, hearing and equilibrium.

(1) **Cranium (Brain case)** : Cranium stabilize the position of brain. In skull of man all eight bones are articulated with each other to form the cranium as follows –

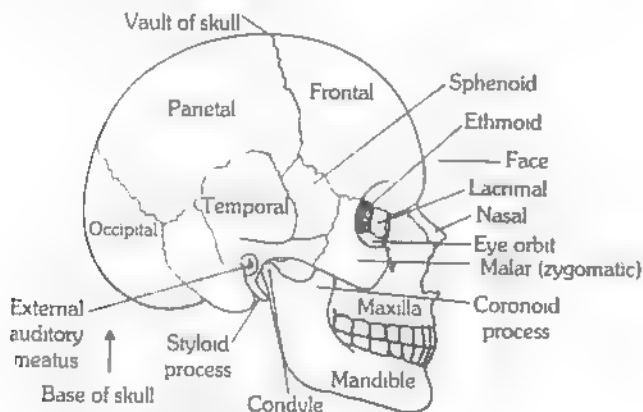


Fig : 5.5-3 Human skull viewed from right side

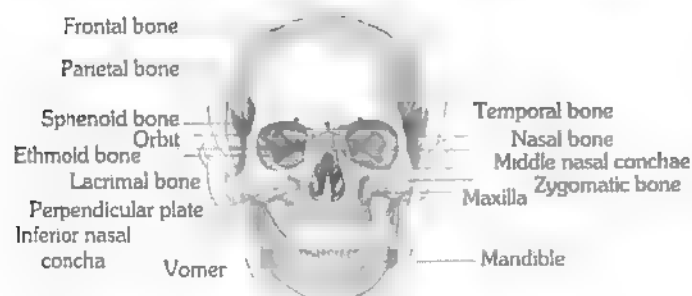
Table : 5.5-2 Bones of cranium

Name	No.	Description
Frontal	1	Forms the forehead (anterior or front part of the top of cranium) and some upper parts (roofs) of eye orbits or sockets and nasal cavities. A newborn infant displays a faint suture in midline of frontal, indicating that adult frontal is actually formed of two completely fused frontal. Frontal suture between two frontal disappear by age 6 years. If persists throughout life referred as metopic sutures.
Parietals	2	Articulated to and situated just behind frontal. Form the main parts of bulging top and sides of cranium.
Occipital	1	Articulated to and situated just behind parietals. Forms posterior (back) and lower (base) parts of cranium. Foramen magnum is a large perforation in this bone. On each side of the foramen, the occipital bears a prominent elevation called occipital condyle. The condyles articulate the skull with first vertebra (axis). Thus, human skull is dicondylic.
Temporals	2	Form lower parts of right and left sides of cranium, as well as, the floor of cranial cavity. These house structures of internal and middle ears and form a part of external auditory meatus. The middle ear of each side encloses the three small ear ossicles – malleus, incus and stapes. The mastoid process with mastoid air cells in adult.
Sphenoid	1	A typically butterfly-shaped bone that forms the middle and anterior parts of base of cranium in front of occipital in the middle and temporals on the sides. It articulates with all skull bones, keeping these firmly together. It also forms parts of lateral walls and floors of eye orbits. Sphenoid with sella turcica depression for pituitary body.
Ethmoid	1	A small, irregular bone in front of sphenoid and behind nasal bones. It fashions the front (anterior) extremity and closer of cranial cavity. It also contributes to the architecture of eye orbits and proximal parts of nasal chambers.

(2) **The facial region** : This is the front or anterior part of our skull comprising of 14 bones as follows :

**Table : 5.5-3 Facial bones**

Name	No.	Description
Nasals	2	Small, oblong bones in middle of upper part of face, forming proximal part of the bridge of our nose. The remaining, lower part of our nose is formed of cartilage.
Inferior nasal conchae (Turbinates)	2	Two highly coiled, scroll-like processes of ethmoid bone, called conchae project into each nasal cavity from lateral wall of the proximal bony part of concerned nasal chamber. One ethmoidal concha is superior (uppermost). The other one is called middle concha, because it is followed by a thin, separate scroll-like bone which is named inferior nasal concha or turbinate.
Vomer	1	A thin, elongated, platelike bone, forming a part of the septum which separates the two nasal cavities.
Lacrimal	2	Small and thin, finger-shaped bones, each located in front part of the medial (inner) side of corresponding eye orbit. These form a part of the passages of corresponding tear ducts.
Zygomatics (Malars)	2	Cheek-bones; form the prominences of our cheeks and parts of the floor and side walls of eye orbits.
Palatines	2	L-shaped bones that form the back (posterior) part of our hard palate (roof of mouth). Also contribute to the framework of nasal cavities and floor of eye orbits.
Maxillae	2	Large, upper jaw bones that form the major part of our face and upper jaw. Comprise entire front (anterior) part of our hard palate. Also contribute to the architecture of eye orbits and nose. Bear the teeth of upper jaw.
Mandible	1	Largest bone of our face, and strongest of all bones of the body. Forms entire lower jaw and bears all lower jaw teeth. Articulated with temporal bones of skull. Only skull bone that moves.

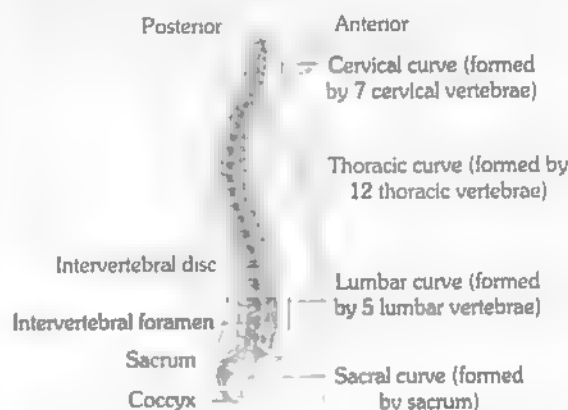


**Fig : 5.5-4 Human skull viewed from the front**

## Vertebral column

It is our backbone which extends in the mid axis of the back (posterior) part of our trunk from head to the lower (inferior) extremity of trunk. Vertebral column of vertebrates is a modification of notochord. Together with the sternum and rib, it forms the supporting frame work of our trunk. It supports and rotate the head, suspends the viscera, protect vital organs, provides attachment to limb girdles, facilitates some movement of the trunk and houses the spinal cord. Vertebral column make two-fifth of total weight of body. The length of human vertebral column is 71 cm. (28 Inc.) in adult male and about. 61 cm (24 inches) in an average adult female.

**Curvatures of vertebral column** : In a foetus, there is only a single anteriorly concave curve, in adult there are 4 curves like, cervical, thoracic, lumbar, and sacral. Cervical and lumbar are anteriorly convex, while thoracic and sacral are anteriorly concave. At approximately 3<sup>rd</sup> month after birth, when an infant begins to hold its head erect, cervical curves develops. Later, when the child sits up, stands, and walks, the lumbar curves develops. The thoracic and sacral curves retains anterior concavity of foetus thus are called 'Primary curves'. The cervical and lumbar curves are modification of the original foetal curves, and are called as "Secondary curves".



**Fig : 5.5-5 Right lateral view showing four normal curves**

The curves of vertebral column are important because they increases its strength, help to maintain balance in upright position absorb shock during walking and running and help to protect the column from fracture. Certain abnormalities of curvature are :

(i) **Kyphosis** : Exaggeration of thoracic curve, resulting in "round-shouldered" appearance, also called hunch back.

(ii) **Lordosis** : An exaggeration of lumbar curve, also called sway back.

(iii) **Scoliosis** : An abnormal lateral curvature in any region of spine.

The vestigial notochord called nucleus pulposus is found in intervertebral disc. Inter-vertebral disc is fibro cartilagenous disc present between centrum of vertebrae.

## Structure of Typical vertebrae

(1) **Neural arch** : It arises from the dorsal side of the centrum and encloses a neural canal for the spinal cord. The arch may be produced into a dorsal process, the neural spine, which may be elongated pointed or flattened and directed upwards or backwards.



(2) **Transverse processes** : These are lateral extension of neural arch and centrum. There may be two types of these processes a more dorsal diapophysis arising from the base of neural arch and a lateral parapophysis arising from the side of the centrum.

(i) **Diapophysis** (*dia- two; apo- from; physis - growth*) : These paired processes are directed differently and provide attachment to the tubercular processes of ribs. They are commonly known as transverse processes and are found in amphibians and other higher vertebrates.

(ii) **Parapophysis** : These paired outgrowths are similar to diapophysis and are common in fishes.

(iii) **Zygapophysis** : These are paired and flat articular surfaces, which check the dislocation of the vertebrae. These are the only structures which enable to identify the anterior and posterior faces of vertebra.

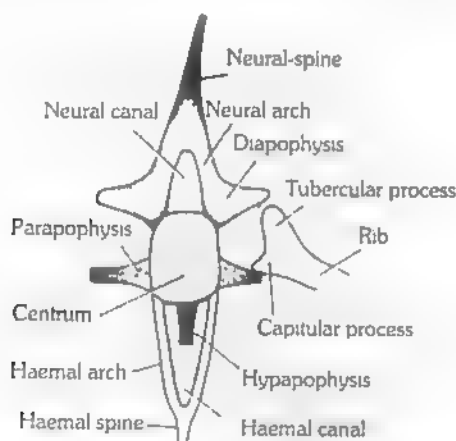


Fig : 5.5-6 Hypothetical typical vertebra (front view)

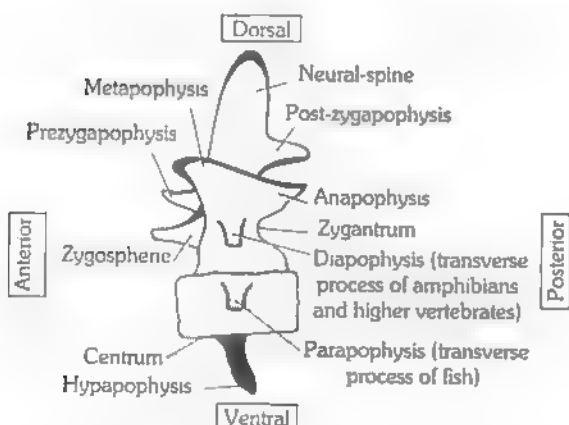


Fig : 5.5-7 Hypothetical typical vertebra (side view)

(v) **Hypapophysis** : It is a mid-ventral process which arises from the centrum. It may be directed forwards or backwards as in certain reptilian, avian and mammalian vertebrae.

(v) **Metapophysis** : These are paired swellings or outgrowths having broad base and arising from just above the prezygapophyses. They are directed forwards and upwards, but their articular facets look slightly downwards. They are found in certain mammalian vertebrae.

(vi) **Anapophysis** : These are paired, slender and short processes which arise just below the postzygapophysis. Their articular facets look slightly upwards and receive for the parapophysis.

(3) **Haemal arch** : It surrounds the haemal canal which allows the blood vessels of the tail region to pass. It may be produced into a haemal spine below e.g., in fishes. The haemal arch of the caudal vertebrae of reptiles is called chevron bone. It is usually Y-shaped.

(4) **Centrum** : The part of vertebra attached to second by centrum. On the basis of centrum vertebrae may be of following type-

(i) **Procoelous-vertebrae** : Anterior end is concave and posterior end is convex. e.g., 2<sup>nd</sup> to 7<sup>th</sup> vertebra of frog. Reptile (Lizard)

(ii) **Ophisthocoelous vertebrae** : Anterior end is convex and posterior end is concave. e.g., Fishes, snake and crocodile only.

(iii) **Heterocoelous vertebrae** : Anteriorly convex from dorsal to ventral and concave from side to side. On posterior side concave from dorsal to ventral and convex from side to side (saddle shaped). e.g., Birds.

(iv) **Acoelous vertebrae** : Also known as Amphiplatyon. No cavity in centrum so centrum is flat. e.g., Mammals (man, Rabbit)

(v) **Amphicoelous vertebrae** : Cavity present on both side of centrum. e.g., VIII<sup>th</sup> vertebra of frog. All vertebrae of scoliodon (Dog fish)

(vi) **Amphidiccondylar (Biconvex)** : Biconvex, condyle on both side. e.g., IX<sup>th</sup> vertebra of frog.

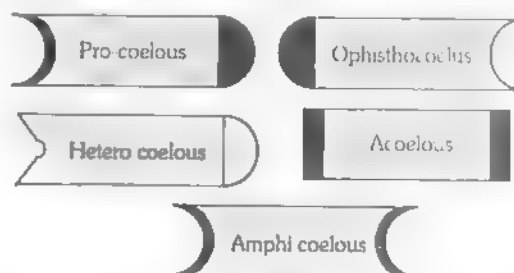


Fig : 5.5-8 Types of Centrum

**Vertebral column of man** : Made up of pieces of bones known as vertebrae. Vertebrae of man are acoelous i.e. Centrum is flat and without cavity (Amphiplatyon). Vertebral column is also known as spinal column or backbone.

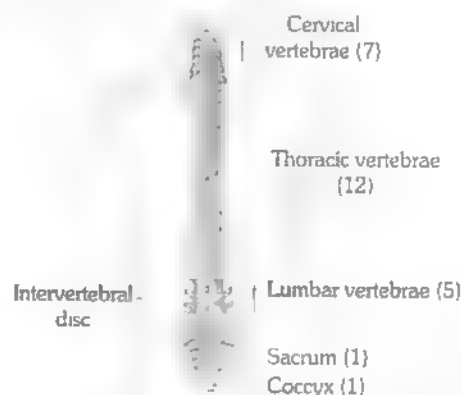
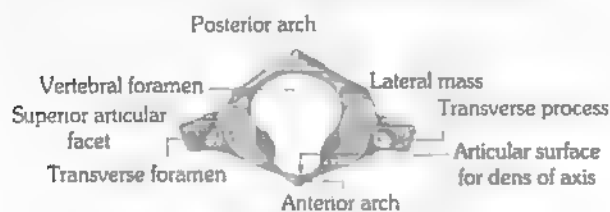


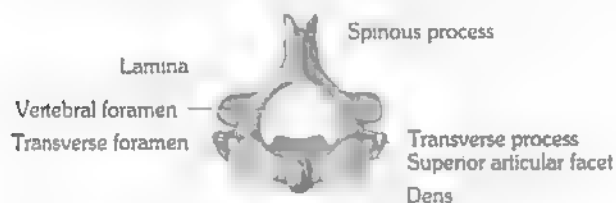
Fig : 5.5-9 Anterior view showing regions of the vertebral column

**(1) Atlas vertebra**

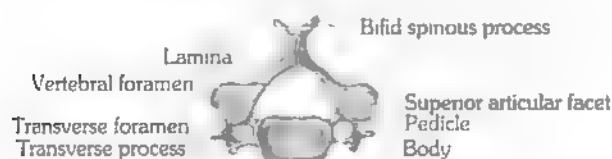
- (i) First cervical vertebra.
- (ii) Body is formed of vertebral arch transverse process.
- (iii) It supports the globe of the head like the earth by the atlas (super man).
- (iv) Centrum is absent.
- (v) Neural spine absent.
- (vi) Transverse process are long with transverse foramen.

**Fig : 5.5-10 Atlas****(2) Axis vertebra**

- (i) Second cervical vertebra.
- (ii) Centrum acoelus.
- (iii) Odontoid process or dens present, which is modified centrum of Atlas.
- (iv) It is pivot for rotation of atlas and head around odontoid process. Transverse process small.

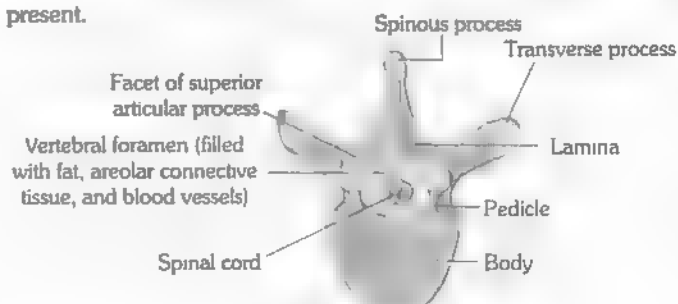
**Fig : 5.5-11 Axis-vertebrae****(3) Typical cervical vertebra**

- (i) Long neural spine.
- (i) Centrum acoelus.
- (ii) Transverse process are large.
- (iv) Vertebrateal canals present.
- (v) Vertebrateal canals also known as foramina transversaria.

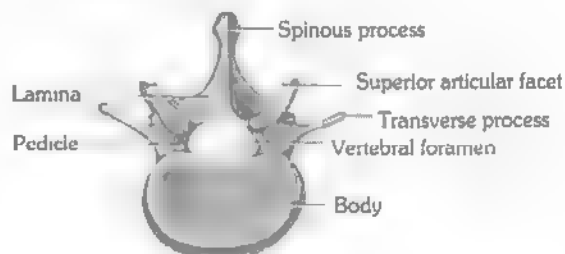
**Fig : 5.5-12 Cervical (Typical)****(4) Thoracic vertebra**

- (i) Centrum acoelus.
- (i) Neural canal is formed by union of two neural arches.
- (ii) Neural spine is flat & long directed backward
- (v) Club shaped transverse process
- (v) Neural arch with superior articular process.

- (vi) Two demifacets for articulation of head of a rib are present.

**Fig : 5.5-13 Thoracic-vertebrae****(5) Lumbar vertebra**

- (i) Centrum acoelus.
- (ii) Neural spine well developed.
- (iii) Transverse process are thin and long.
- (iv) Small accessory process present near the root of each transverse process
- (v) It is the largest vertebrae

**Fig : 5.5-14 Lumbar-vertebrae**

- (6) **Sacrum** : It is a triangular bone formed by fusion of 5 sacral vertebra.

- (i) Fusion normally begins between 16 to 18 years of age and is completed by 30 yrs. of age.

- (ii) Serves as strong foundation for pelvic girdle.
- (iii) Sacrum with 4 pairs of anterior and posterior sacral foramina.

- (iv) Lateral part of sacrum articulate with ilium of hip bone.
- (v) Female sacrum is shorter, wider and more curved between S<sub>2</sub> and S<sub>3</sub> the male sacrum is longer, narrower, and less curved.

- (vi) In birds some of the vertebrae are fused to form synsacrum. (Last thoracic+ Lumbar+ Sacral+ One or two caudal)

**(7) Coccyx**

- (i) It is formed by fusion of four coccygeal vertebrae.
- (ii) It is last section of backbone.
- (iii) It is small triangular bone.
- (iv) Two coccygeal cornua project upto articulate with sacral cornua.
- (v) Rudimentary transverse process

(vi) Fusion generally occurs between 20 and 30 years of age.

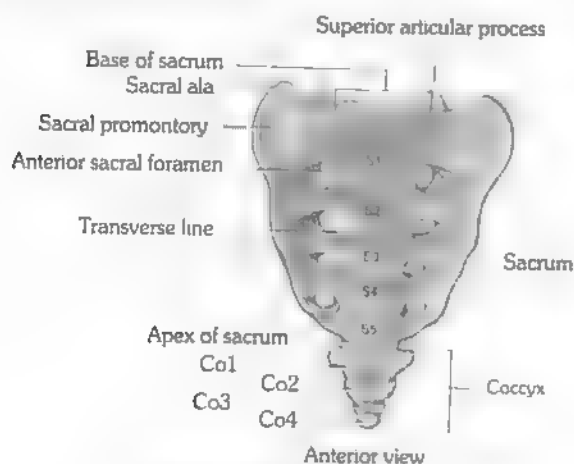


Fig : 5.5-15 Human sacrum and coccyx

### Thoracic basket

#### (1) Ribs

**Structure :** The ribs are curved bars, which movably articulate with the thoracic vertebrae at the back and while with the sternum in front all collectively forming a bony cage, the thoracic basket. These are 12 pairs of ribs. The upper seven pairs of ribs are attached in front directly to the sternum by hyaline cartilage. These are called true rib. The next three pairs of rib costal cartilage attach indirectly to sternum. They are termed false ribs. The lower two pair of ribs are free in front they are known as floating ribs. Tenth rib is also usually floating in Japanese and some other people.

A rib consists of two parts, Vertebral and Sternal. The vertebral part is long and bony. It articulates with the thoracic vertebrae by 2 facets, the capitulum and tuberculum, (Ribs of mammal and birds are bicephalous) in the first nine ribs and by a single facet, the head in the remaining vertebrae. The sternal part is short and cartilaginous. It articulates with the sternum or sternal part of its upper rib.

Human thorax is wider from side to side than from front to back. This is an adaptation for the upright posture of the body. It helps to maintain equilibrium. In birds an uncinate process is present in ribs for muscles attachment.

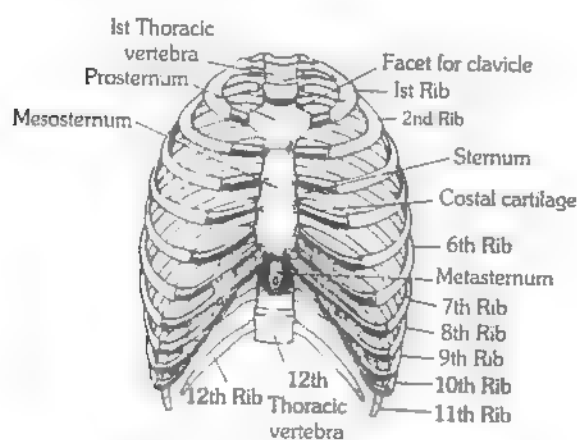


Fig : 5.5-16 Bones of thorax (front view)

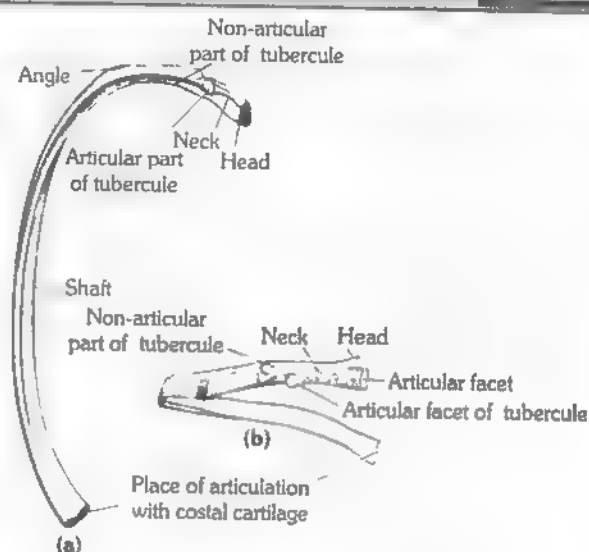


Fig : 5.5-17 A typical rib of left side (a) Inferior aspect; (b) Posterior aspect

**Function :** The ribs serve three important functions –

- (i) They protect the heart, large blood vessels and lungs.
- (ii) They bear respiratory muscle (external and internal intercostal muscle).
- (iii) Lower two pair of ribs protect the kidney. (11<sup>th</sup> and 12<sup>th</sup>)

#### (2) Sternum

##### Structure

- (i) It is a bone of chest.
- (ii) It is absent in fish, Turtle.
- (iii) It is associated with pectoral girdle in amphibia.
- (iv) In man it is made up of cervical manubrium (presternum), mesosternum and xiphoid process (Metasternum).
- (v) In male it is nearly 17 cm long.
- (vi) Manubrium is broad and thick.
- (vii) Mesosternum is made up of fine sternbrae.
- (viii) Metasternum is represented by xiphisternum which is smallest broad and thin. In mammal a cartilaginous plate is attached with xiphisternum known as xiphoid cartilage (hyaline).

□ Sternum = manubrium + 5 sternbrae + xiphisternum.

**Function :** The sternum has two functions –

- (i) It takes part in the formation of the protective thoracic basket.
- (ii) It plays a role in the respiratory mechanism.

### Appendicular skeleton

It forms the bony frameworks of limbs and their supporting girdles, and includes 126 bones as follows –

1. Upper extremities	2. Lower extremities
(i) Pectoral girdle	(i) Pelvic girdle 2
<ul style="list-style-type: none"> <li>Clavicle (2)</li> <li>Scapula (2)</li> </ul>	
(ii) Upper limbs (arms) 60	(ii) Lower limbs 60

**Girdles :** The girdles give articulation to the limb bones. There are two types of girdle pectoral girdle (shoulder girdle) and pelvic girdle (Hip girdle). Each girdle is made up of similar right and left halves (as innominate).

### (1) Pectoral girdle

**Structure :** Each half (Os innominate) of the girdle mainly comprises a large, flattened and triangular cartilage bone, the scapula (shoulder blade). The broader side has a narrow strip of cartilage called suprascapula. The dorsal surface of scapula has a median longitudinal ridge called acromian spine, which successively becomes more and more prominent towards the narrower end of scapula and then, projects beyond this end as a distinct acromian process. Another prominent metacromian process projects horizontally from the base of acromian process. At its narrow end, the scapula is itself fused with an inwardly bent, knob like coracoid process. A deep, cup like concavity the glenoid cavity is located at the end of scapula close to coracoid process. The head of humerus (bone of upper arm) fits into this cavity. Another component of each half of pectoral girdle is a long and slender, rod-like membrane bone the clavicle, articulated with the acromian process. The other end of clavicle is connected with pre sternum by means of an elastic ligament. Clavicle is also called collar bone.

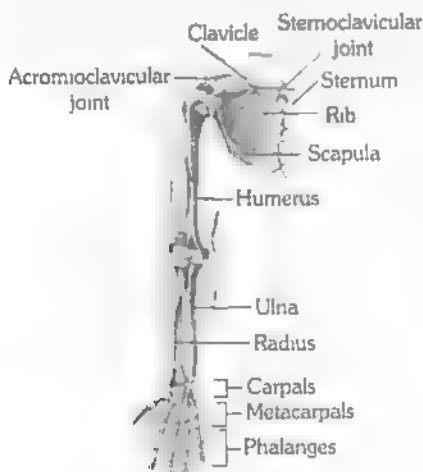


Fig : 5.5-18 Scapula-pectoral girdle

**Function :** The pectoral girdle serves two functions –

- (i) It provides articulation to the arm bones.
  - (ii) It affords attachment to certain muscles of the arm.
- (2) **Pelvic (Hip) girdle**

**Structure :** It is located in the lower part of the trunk. It consists of 3 bones – upper ilium, lower ischium and inner pubis, fused to form a stout hip bone, the innominate. Ventral wall of pubis has a small bone called cotyloid. Acetabulum is formed by ilium, ischium and pubis, but in mammals pubis is replaced by cotyloid bone. Pubic symphysis is present in mammals. Below the acetabulum, the innominate has a large oval gap, the obturator foramen (ischio-pubic foramen). The two innominate bones and sacrum together form a sort of bowl, the pelvis, that supports the lower abdominal viscera. This is also an adaptation for upright posture of the human body. The female pelvis is larger and has a broader front and larger bottom opening than the male pelvis. This

is an adaptation for childbirth. In man ischial tuberosity or sitting bone is present in ischium.

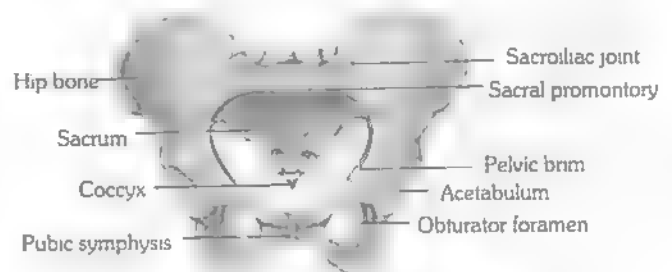


Fig : 5.5-19 Man-male pelvis (Anterior view)

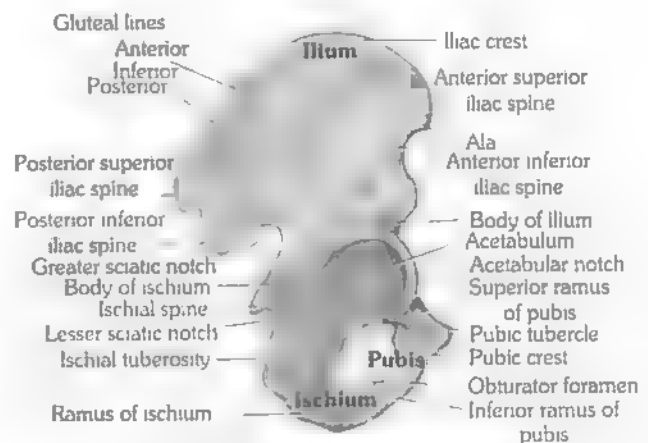


Fig : 5.5-20 Man-pelvic girdle (Lateral view)

**Functions :** The pelvic girdle serves the following functions –

- (i) It provides articulation to the bones of the leg.
- (ii) It contributes to the formation of a bowl for the support and protection of abdominal viscera.
- (iii) It transfers the weight of the body to the leg.
- (iv) It provides the attachment to certain leg muscles.
- (v) Support vertebral column.

**Limb bones :** Limb are of two types fore limb and hind limb.

### (1) Bones of fore limbs

#### Structure

- (i) Humerus or arm bone or bone of upper arm, is longest and largest bone of upper limb.
- (ii) It articulates proximally with scapula and distally at the elbow with both ulna and radius.
- (iii) Humerus proximal end with greater and lesser tuberosity tubercle.
- (iv) Both radius and ulna with nutrient foramina.
- (v) Radius present towards thumb side.
- (vi) Ulna present towards little finger side.
- (vii) It includes Humerus + Radius & ulna + Carpals + Meta carpals + Phalanges.
- (viii) Humerus is characterised by the presence of deltoid tuberosity for the attachment of muscles

(ix) Distal end of humerus at the elbow joint is like pulley and called trochlea. Its groove is called olecranon fossa whose basal part is marked by a supratrochlear foramen for the passage of brachial artery and nerve.

(x) Humerus is characterised by arterial foramen.

(xi) Head of the humerus articulate with glenoid cavity of pectoral girdle

(xii) Radius is smaller and ulna is larger, were bones of fore arm.

(xiii) Styloid process is present in distal end of ulna and radius both.

(xiv) Olecranon process is present in ulna. Proximally, which forms prominence of elbow.

(xv) Trochlear notch is formed by ulna which is also known as sigmoid notch.

(xvi) Carpals or wrist bone are eight in number, joined to one another by ligaments. Carpals are arranged in 2 rows, with 4 bones in each row.

(xvii) Metacarpals are five in number, and phalanges are - fourteen, phalanges formula = 2, 3, 3, 3, 3.

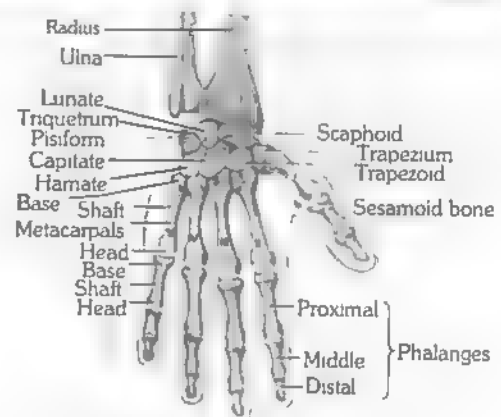


Fig : 5.5-23 Hand (Posterior view)

**Special features :** In the human arm, (i) The joints are more movable than in the forelimbs of animals (ii) Metacarpals form a wide palm and (iii) Thumb is opposable. The differences in structure are correlated to the differences in function. Animals use their forelimbs mainly for locomotion whereas man uses the arms for work (grasping).

**Function :** Bones of the arms provide strength to make the arms effective in working with them.

## (2) Bones of hind limbs

### Structures

(i) It includes Femur + Tibia and Fibula + Tarsals + Metatarsals + Phalanges

(ii) Fovea capitis is depression in head of femur.

(iii) Femur is longest and strongest bone of body.

(iv) Femur is known as bone of thigh

(v) Greater trochanter, lesser trochanter 3<sup>rd</sup> trochanter are present in femur, of thigh and buttock muscles.

(vi) Patellar groove is found in distal end of femur.

(vii) Fibula is smaller and associated with knee joint.

(viii) Tibia is larger, also called shin bone. It bears a weight of body.

(ix) Tarsal bones are seven.

(x) Metatarsals are five.

(xi) Phalanges are fourteen.

(xii) Phalanges formula = 2, 3, 3, 3, 3

(xiii) Patella form knee cap.

(xiv) Patella is formed by sesamoid bone. Fabella also example of sesamoid bone.

(xv) Thumb of foot is called hallux.

(xvi) Ankle bones have 7 tarsals and arranged in two rows. The first row have talus and calcaneus and second row with cuboid, Navicular, and I, II, III cuneiform.

(xvii) Nutrient foramen present in Tibio - fibula bone. Tibia fibula is longest bone in frog.

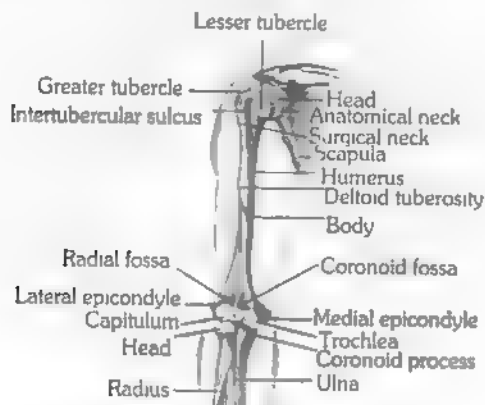


Fig : 5.5-21 Humerus (Anterior view)

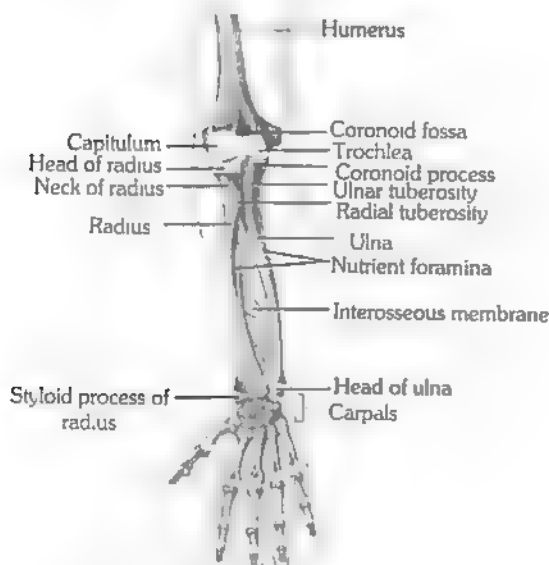


Fig : 5.5-22 Radio-ulna (Anterior view)

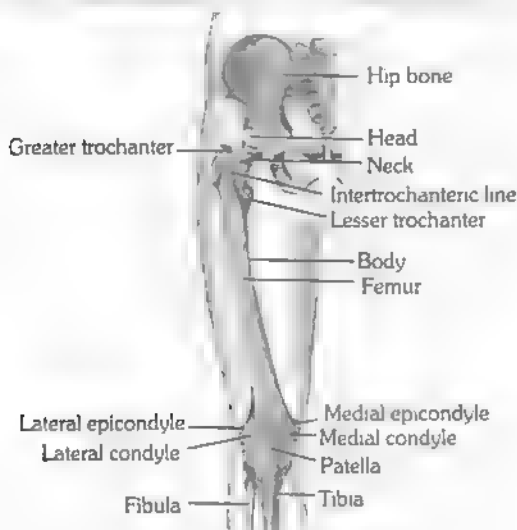


Fig : 5.5-24 Femur (Anterior view)

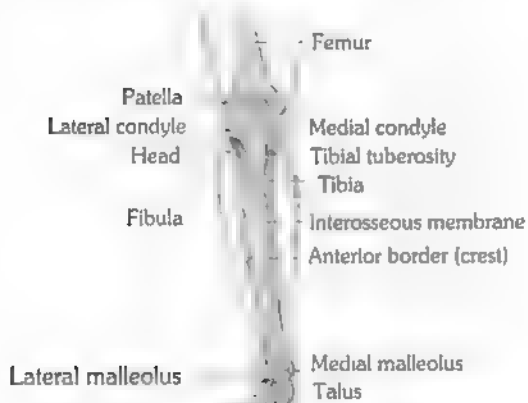


Fig : 5.5-25 Tibia-fibula (Anterior view)

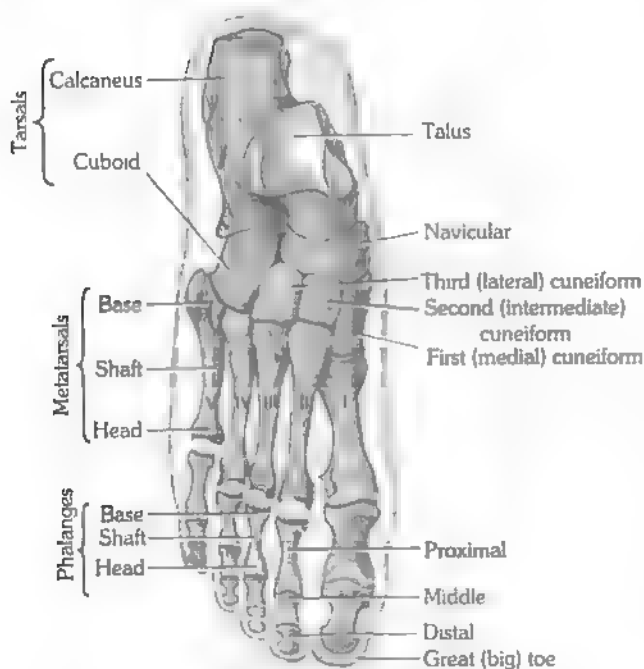


Fig : 5.5-26 Foot (Inferior view)

**Special features :** All the bones of the legs are more massive than the bones of the arms because the legs alone support the body on the ground and are used in locomotion. The broad feet provide an additional stable support in the upright posture.

**Function :** The bones strengthen the legs to bear body weight, to balance the body while standing and to aid in locomotion.

Table : 5.5-4 Total number of skeletal bones : 206 Bones

Skull	29 Bones	Facial region	14 Bones
Cranium	8 Bones	Nasals	: 2 Bones
Occipital	: 1 Bone	Vomer	: 1 Bones
Parietal	: 2 Bones	Turbinates	: 2 Bones
Frontal	: 1 Bones	Lacrymal	: 2 Bones
Temporal	: 2 Bones	Zygomatic	: 2 Bones
Sphenoid	: 1 Bone	Palatine	: 2 Bones
Ethmoid	: 1 Bone	Maxilla	: 2 Bones
		Mandible	: 1 Bones
Coccyx	: Fusion of 4 coccygeal vertebrae	Vertebral formula = 33 (child)	
In new born baby	: 5 sacral vertebrae	C TH L S C	
In adult	: Only one sacrum	↓ ↓ ↓ ↓ ↓	
Ribs in man	: 12 pairs	7 12 5 5 4	
True ribs	: 7 pairs	Sacral coccygeal	Vertebral column
False ribs	: 3 pairs	= 26 (In adult)	
Floating ribs	: 2 pairs	C TH L S C	
Ear ossicles	6 Bones	↓ ↓ ↓ ↓ ↓	
Malleus	2 Bones	7 12 5 1 1	
Incus	2 Bones		Sacrum coccyx
Stapes	2 Bones		
Hyoid	1 Bone		
		Vertebral column	: 26 Bones
		Sternum	: 1 Bone
		Ribs	: 24 Bone
		Pectoral girdle	: 4 Bones
		Pelvic girdle	: 2 Bones
		Fore limbs	: 60 Bones (both)
		Hind limbs	: 60 Bones (both)
		Total	: 206 Bones
		In child	: Bones 330

## Joints

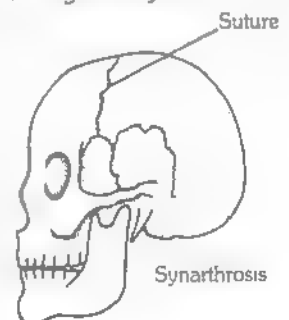
There are many articulations or joints present in the skeleton. Joint or articulation is a point of contact between bones. Joints are classified based upon their structure and the kinds of movements which they permit. Three main types of joints are –

(1) **Immovable joints (Synarthrosis)** : No joint cavity, no movement possible. These joints include –

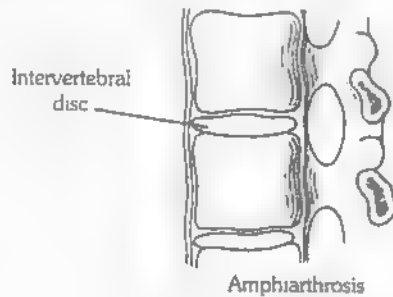
(i) **Sutures** : Found between skull bones, sutures are fixed or fibrous joints, articulating bones are held together by white fibrous tissue.

(ii) **Gomphosis** : It is a type of fibrous joint in which cone shaped peg fits socket. Teeth in mandibles, and maxillary bones.

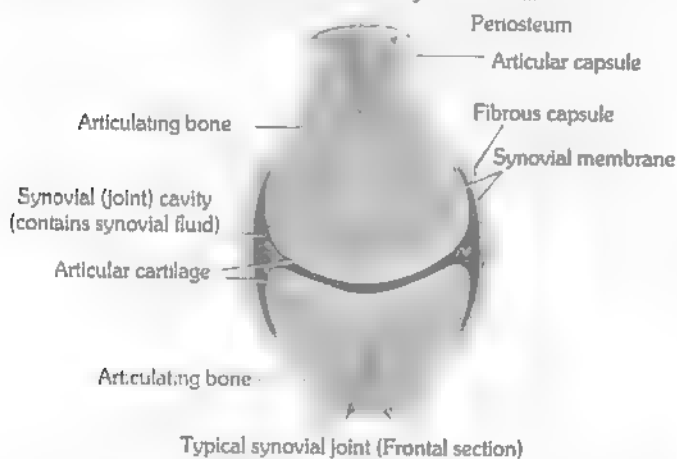
(iii) **Syndesmosis** : It is type of fibrous joint with more fibrous tissue than sutures. e.g., distal articulation between tibia and fibula



(2) **Imperfect joints (Amphiarthrosis)** slightly movable : Joints in which synovial cavity is absent. Permit a small amount of movement. Fibrocartilage is placed between the bones. These are cartilaginous joints e.g., Pubic symphysis, between bodies of the vertebrae, between the manubrium and the body of sternum, sacroiliac joint in frog.



(3) **Perfect joints (Diarthrosis)** freely movable : Synovial cavity and ligaments are present. These are typical joints having articulate surface and synovial capsule. Synovial fluid act as a grease in the joint e.g., Joints of elbow, ankle, wrist, hip, knee. Articular cartilage covers the surface of articular bones. Articular cartilage of synovial joint is hyaline cartilage. Synovial joints are surrounded by tubular articular capsule. The articular capsule consists of two layers, outer fibrous capsule and inner synovial membrane. The synovial membrane secretes synovial fluid which lubricates and provides nourishment to articular cartilage. In old age stiffness of joints is due to the decrease in synovial fluid.



(i) **Ball and socket joint** : Also known as enarthrosis. Ball of one bone articulate in socket of another bone. e.g., head of humerus and glenoid cavity of pectoral girdle, femur and acetabulum of pelvic girdle, joint between incus and stapes.

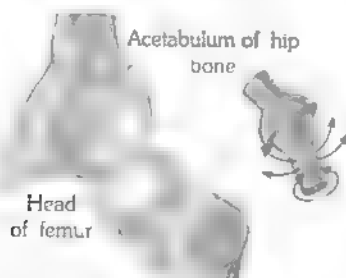


Fig : 5.5-27 Ball-and-socket joint between head of the femur and acetabulum of the hip bone

(ii) **Hinge joint** : Also known as ginglymus. Movement is possible in one direction only. e.g., Joint of malleus and incus, knee joint, elbow joint, articulation joint of lower jaw, joint of phalanges of digits.

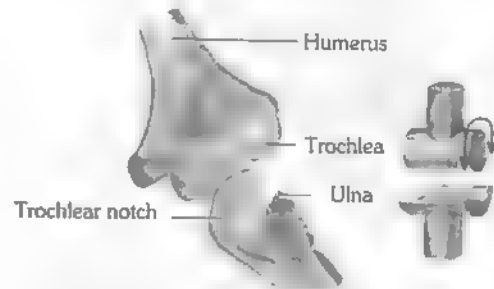


Fig : 5.5-28 Hinge joint between trochlea of humerus and trochlear notch of ulna at the elbow

(iii) **Pivot joint** : Also known as rotatoria and helps in turning movement. One bone is fixed and second articulate. e.g., Atlas and axis of skull rotate with axis vertebra also known as atlanto axial joint.

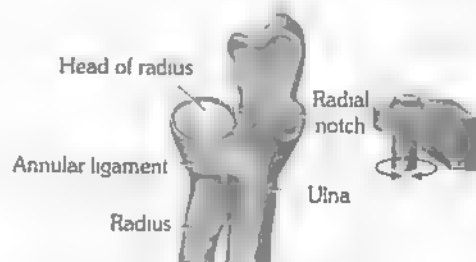


Fig : 5.5-29 Pivot joint between head of radius and radial notch of ulna

(iv) **Gliding joint** : Also known as arthrodial, limited movement in all direction. e.g., Tarsals bones of ankle zygapophysis of vertebrae, Radius and Ulna.

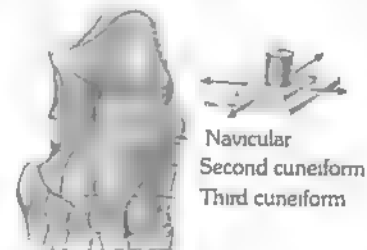


Fig : 5.5-30 Gliding joint between the navicular and second and third cuneiforms of the tarsus in the foot

(v) **Saddle joint** : It is ball and socket like joint but not developed fully. e.g., metacarpal of thumb, and carpals of hand.

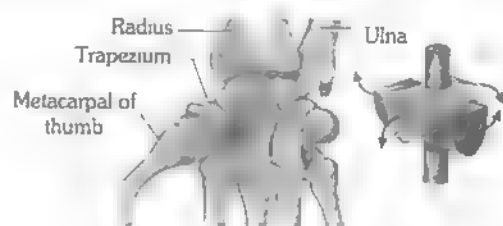
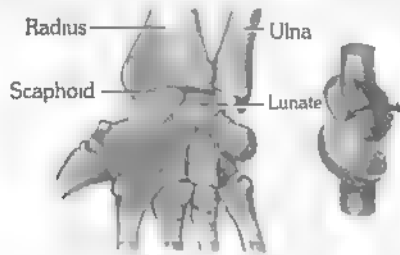


Fig : 5.5-31 Saddle joint between trapezium of carpus (wrist) and metacarpal of thumb

(vi) **Condylloid joint** : Also known as ellipsoidal joint is biaxial where oval condyle of one bone fits into an elliptical cavity of another bone. e.g., joint between radius and carpals at wrist.



**Fig : 5.5-32 Condylloid joint between radius and scaphoid and lunate bones of the carpus (wrist)**

### Characters, adaptation, types, movement and disorder of bones

(1) **Characteristics of female's skeleton** : In female's skeleton, (i) skull is lighter, (ii) shoulders are narrower (iii) sacrum is shorter but wider, (iv) pelvis is wider, has a broader front and larger bottom opening to facilitate child birth, and (v) coccyx is more movable than in male's skeleton

(2) **Adaptations in skeleton for upright posture** : Human skeleton shows many adaptive features for upright posture –

- (i) Foramen magnum is directed downward so that the head may rest vertically on the vertebral column.
- (ii) Four curves in the backbone keep the centre of gravity near the heels. This helps to maintain balance and makes walking erect on two legs much easier.
- (iii) Thorax is wider from side-to-side than from front-to-back. This helps to maintain equilibrium.
- (iv) Bowl-like pelvis supports the lower abdominal viscera.
- (v) Metacarpals form a wide palm and the pollex is opposable. This makes the hand a grasping organ to work with it.
- (vi) Leg bones are stronger than the arm bones as the femur carry the entire weight of the body in locomotion.
- (vii) Broad feet provide stability in the upright posture.
- (viii) The arches of the feet enable the body to move with a degree of springiness.
- (ix) Increased mobility of the neck to see all round.
- (x) Increased skeletal height provides greater range of vision.

(3) **Types of bones** : Bones are divided into 4 categories regarding their size and shape –

- (i) **Long bones**, e.g., humerus of upper arm, radius and ulna of forearm, femur of thigh, and tibia and fibula of leg.
- (ii) **Short bones**, e.g., metacarpals of palm and metatarsals of foot, phalanges of fingers and toes.
- (iii) **Flat bones**, e.g., scapula of shoulder girdle, sternum, cranial bones.
- (iv) **Irregular bones**, e.g., vertebrae, carpals of wrist and tarsals of ankle.

(4) **Bone movement** : Movements of bones occur only at the joints. The movements are brought about by contractions of skeletal muscles inserted into the articulating bones by firm cords of white fibrous tissue called tendons. Cords of yellow elastic tissue, termed ligaments, stabilise the joints by holding the articulating bones together.

(5) **Disorder of skeleton and joints** : Any violent movement, such as jump, fall or knock, may cause injury to the skeleton. The injury can be of 5 types – sprain, dislocation, fracture, arthritis and slipped disc.

(i) **Sprain** : Sprain refers to injury to a joint capsule, typically involving a stretching or tearing of tendons or ligaments. Unfortunately, both these structures have much poorer regenerative power than bone, and once stretched often remain weak. Sprain is often considered a minor disorder, but it may become chronic.

(ii) **Arthritis or Aching Joints** : Arthritis refers to inflammation of the joints. It is a common disease of the old age. Its common symptoms are pain and stiffness in the joints. It has many forms. Three more common forms are described here – osteoarthritis or degenerative arthritis, the rheumatoid arthritis and gout.

(a) **Osteoarthritis** : Secretion of the lubricating synovial fluid between the bones at the joint stops. The smooth cartilage covering the ends of the bones at the joint wears out due to years of use and is replaced by uneven bony spurs. The joint becomes inflamed, its movement becomes painful, and its function is diminished. Such a stiffness or fixation of a joint is also called ankylosis. The condition of osteoarthritis is more or less permanent. It is common in old persons, mainly affecting weight bearing joints.

(b) **Rheumatoid arthritis** : It is a chronic painful inflammation of the synovial membranes of many joints simultaneously. It usually starts in the small joints in the hand and progresses in centripetal and symmetrical manner. In severe cases, it eventually results in crippling deformities. There may be other manifestations such as fever, anaemia, loss of weight and morning stiffness. The rheumatoid arthritis involves erosion of joints. It usually starts at the age of 20 – 40 years, but may begin at any age. It affects the women more often than the men. Rest and exercise under medical advice may give relief.

(c) **Gout** : It is an inherited disorder of purine metabolism, occurring especially in men. Body forms excess amounts of uric acid and the crystals of sodium urate are deposited in the synovial joints, giving rise to severe arthritis. It generally affects one or two joints only. It is very painful, particularly at night, and makes movement difficult. Redness and tenderness may be noticed in and about the affected joint. Gout generally affects the great toe. Occurrence of gout is related to diet. Persons suffering from gout should avoid meat. There is no cure for arthritis. However, pain relieving (analgesic) drugs are available to give comfort.

#### (iii) Osteoporosis

(a) **Meaning** : Osteoporosis is reduction in bone tissue mass causing weakness of skeletal strength (*G. osteon = bone, poros = pore, osis = condition*). It results from excessive resorption of calcium and phosphorus from the bone. There is relatively greater loss of trabecular bone than of compact bone. This leads to vertical compression, or crush fracture, of the vertebrae (which consist primarily of trabecular bone), and fracture of the neck of the femur (which has considerable trabecular bone).



(b) **Causes** : Osteoporosis occurs in postmenopausal women and elderly men. It may result from defective intestinal calcium absorption and menopause. Possible environment factors include smoking, excessive drinking, and decreased exercise. Osteoporosis is more common in women than in men, and in older than in middle-aged persons.

(c) **Symptoms** : Symptoms of osteoporosis are pain in the bone, particularly the back, and vertebral crush, usually in weight bearing vertebrae (thoracic-8 and below).

(d) **Prevention** : Preventive measures in high-risk patients include supplementary calcium and exercise, and, in postmenopausal women, estrogen replacement therapy. Supplementary calcium and sex hormones decrease bone resorption and may arrest or reduce disease progression.

(iv) **Dislocation** : Dislocation is displacement of bones from their normal positions at a joint, for instance, slipping out of the ball of one bone from the socket of another bone into which it is fitted. Dislocation is accompanied by pulling or even tearing of the ligaments. Dislocation also tends to become chronic.

(v) **Slipped disc** : Slipped disc is a displacement of vertebrae and the intervertebral fibrocartilage disc from their normal position. It may result from mechanical injury or defects of ligaments holding the vertebrae together.

(vi) **Fracture** : Fracture is a break of a bone. Fracture occurs rarely in children. The bones of children have a large quantity of organic matter and are, therefore, very flexible and less likely to break. With advancing age, mineral matter (calcium phosphate) is deposited in the bones. This decreases the organic matter, making the bones hard and brittle. Thus, old people are more liable to fracture of bones. Bones fractures are of many types –

(a) **Green-stick fracture** : Fracture in which the bone is partially bent & partially broken, as when a greenstick breaks, occurs only in children.

(b) **Simple or complete fracture** : Bone breaks completely into two parts which remain close to each other.

(c) **Comminuted fracture** : Bone breaks into more than two pieces (smaller fragments between two main fragment,

(d) **Compound fracture** : Bone breaks completely but a fragment pierces out through the skin.

(e) **Evulsive fracture** : A small piece breaks off fully from the bone but remains attached to the ligament. Fractures need surgical treatment for healing and should be promptly and properly attended to

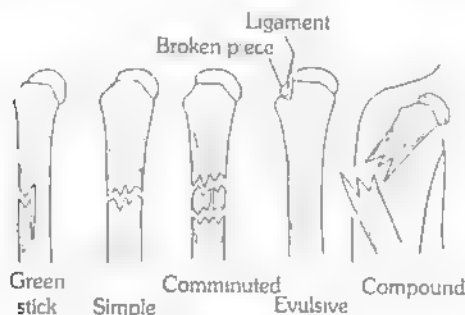


Fig : 5.5-33 Types of bone fracture

(vii) **Bursitis** : Bursitis is inflammation of the bursae present in the joints. It is caused by physical injury or constant pressure on a single joint for a long time.

(viii) **Osteomyelitis** : It is the inflammation of bone due to pus producing organism. It may remain localised or spread inside involving various parts including bone marrow.

## Body muscles

In the body of all the multicellular animals muscles are found. The movement of the body takes place by these muscles. If the muscles become weak, the functioning of the body become difficult. The muscles are capable of contraction and relaxation, hence these are elastic.

A muscle can pull a part of the body by its contraction (shortening). It cannot push that part by relaxation (elongation). Hence, the muscles are typically arranged in antagonistic (opposing) pairs, one muscle moves a body part in one direction by its contraction and the other muscle moves that part in the opposite direction by its contraction. Of course, when one muscle contracts, its opposing muscle relaxes. The principle of antagonistic muscles is true of both vertebrate as well as invertebrate muscles. Animal movements depend upon interaction of muscles and skeleton.

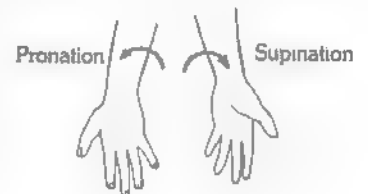
(1) **Action of body muscles** : As mentioned above, the body muscles are arranged in antagonistic (opposing) pairs. One muscle of a pair moves a body part in one direction and the other in the opposite direction. For example, the muscle named biceps brings the forearm toward the upper arm, and the muscle called the triceps moves the forearm away from the upper arm. When biceps contracts to cause movement, the triceps relaxes to allow that movement to occur and vice versa. Similar pairs of opposing flexor and extensor muscles occur at the wrist, ankle and knee. The type of movement that results from the contraction of a muscle depends entirely upon the way the muscle is attached to the levers of the skeleton.

(2) **Classification of body muscles** : According to the type of motion they cause, the muscles are divided into the following types. The muscles that act together to produce a movement are called synergists and the muscle that act in opposition to each other are antagonists. The muscles that act most powerfully during any given movements are called prime movers.

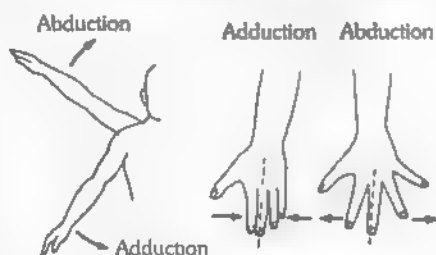
(i) **Flexor and Extensor** : Muscles that bend one part over another joint is called flexor. Extensor muscle is antagonist of flexor muscle. The contraction of an extensor extends a joint by pulling one of the articulating bone apart from another.



(ii) **Pronator and Supinator** : The contraction of a pronator rotates the forearm to turn the palm downward or backward. Supinator is antagonist of pronator. A supinator contracts to rotate the forearm and thus to make palm face upward or forward.

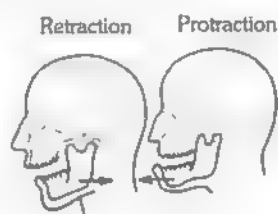


(iii) **Abductor and Adductor** : An abductor contracts to draw a bone away from the body midline. Muscle that brings the limb away from midline is called abductor. An adductor draws a bone towards the body midline. Muscles that bring the limb towards midline is called adductor. Abductor muscle is antagonist of adductor muscle. Abduction is elevation and adduction is depression.

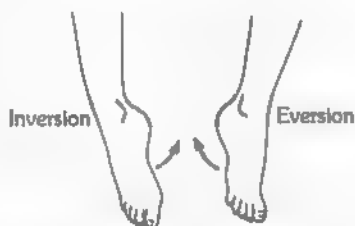


Abductor muscle is antagonist of adductor muscle. Abduction is elevation and adduction is depression.

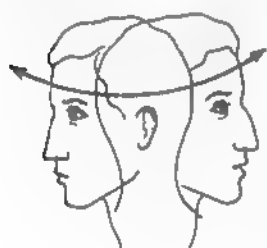
(iv) **Protractor and Retractor** : Protractor muscle pulls the lower jaw, tongue and the head forward. Retraction is opposite to protraction. Retractor muscle draws the lower jaw, tongue and the head backward.



(v) **Inversion and Eversion** : Turning of feet so that the soles face one another in inversion. Eversion is the opposite of inversion. In this movement, the soles of the feet face laterally.



(vi) **Rotation** : Rotation is a term that indicates the partial revolving of a body part on the part's long axis.



Rotation



Circumduction

(vii) **Arrector** : Raises hairs of skin.

(viii) **Levator** : Elevates a part of body.

(ix) **Depressor** : Lowers a part of body

(x) **Agonistic** : Opposed in action by another muscle.

(xi) **Antagonistic** : Counteracts the action of another muscle.

(xii) **Sphincter** : Closes a natural orifice or passage.

(xiii) **Constrictor** : Causes constriction or squeezing.

The adductor and abductor, elevator and depressor, pronator and supinator, and sphincters and dilators are all antagonistic muscles.

### Important muscles

Table : 5.5-5 In man total no. of muscles : 639 muscles

Biceps and Triceps	Arm
Gastrocnemius	Shank of leg
Gluteimaximus	Buttock muscles
Oblique	Eye muscles
Rectus	Eye muscles
Maxillaries	Upper jaw
Pectoralis Major	Chest
Pectoralis Minor	Chest
Mandibularis	Muscle of lower jaw
Latissimus dorsi	Shoulder muscle
External oblique	Lower abdomen
Internal oblique	Lower abdomen
Transversus	Lower abdomen
Rectus abdominis	Lower abdomen
Stapedial muscle / arrector pili	Smallest muscle
Sartorius femoris	Longest muscle
Gluteus maximus	Largest muscle

### Movement and Locomotion

Movement is one of the most important characteristics of living organisms. Nonliving objects do not move. If nonliving objects show movement, that is always due to some external force. For example, the cart is moved by the horse and the fan revolves by the energy of electric current. The movement of a nonliving object is, therefore induced (due to external force) while the movement of living things are autonomic (self sustained). Study of movement is called kinesiology (G. *Kinein* = to move, *Logos* = study). The movement of living systems are thus autonomic or active, that is effected by the organisms themselves without external influences. On the other hand the movement of nonliving systems are induced or passive, i.e., made to occur by external forces. Movement of animals are two main types muscular and non muscular.

(1) **Muscular movement** : Muscular movement are found in the majority of animals brought about by sliding of myofilaments. Muscular movement are further divide into two kinds – Locomotion and movement of body parts.

(i) **Locomotion (locus = place + moveo = to move)** : Locomotion is the movement of an animal as a whole from one place to another.

**Types of locomotion** : Locomotion takes several forms such as walking (man), creeping (earthworm, lizard), cursorial (Horse, flightless birds), hopping (frog, rabbit), running (dog, horse), flying (insects, birds) and swimming (fish, whale).

Animals have suitable adaptations for their specific mode of locomotion. Adaptations for running, hopping, swimming and flying are respectively called cursorial, saltatorial, natatorial, and volant adaptations. Morphogenetic movement, i.e., the streaming of cells in the early embryo to form tissues or organs, may be considered a form of locomotion.

**Advantage of locomotion :** Locomotion is helpful for animals as escape from predators, search of shelter, food and water, shift to favourable environment, reproduction, collect materials for nest building, locate suitable area for breeding and dispersal to new location. All forms of locomotion require energy to overcome two forces that tend to keep the animals stationary. These are friction and gravity.

(a) **Swimming :** Water is a much denser medium than air so body modified for swimming in the form of buoyancy, fusiform body etc. Mode of swimming varies in animals. Fishes swim by moving their body and tail from side to side. Whales and dolphins swim by undulating their body and tail up and down. Insects and 4-legged vertebrates use their legs as oars to push against the water. Cuttle fish and squid are jet-propelled, taking in water and squirting it out in bursts.

(b) **Locomotion on land :** For walking, running, hopping and crawling on land, animal expends energy body to prevent falling down and move forward against gravity. Powerful muscles and strong skeletal support are more important for moving on land than a streamlined body. Creeping animals have their entire body in contact with the ground. Therefore, they make a considerable effort to overcome friction.

(c) **Flying :** Gravity is a major problem in flight. Wings must produce enough lift to make and keep the animal air-borne against the downward force of gravity.

2) **Non-Muscular movement :** Besides locomotion and movements of body parts, some of the cells of multicellular animals move like unicellular organisms.

(i) **Ciliary movement :** The cilia present in the trachea, vasa efferentia and oviducts propel by their movements dust particles, sperms and eggs respectively. The cilia of flame cells of flatworms push excretory materials. Ciliary movements in *Planaria* or *Dugesia* also.

(ii) **Flagellar movement :** The flagella of choanocytes (collar cells) of the sponges maintain a regular current of water in the body. The flagella of certain cells of gastrodermis of hydra help in the circulation of food. Sperms move by flagellar movements.

(iii) **Pseudopodial movement :** Leucocytes and macrophages move by pseudopodial movement.

(iv) **Cytoplasmic streaming movement :** Streaming movement of the cytoplasm is called cyclosis. It is observed in most of the cells

- ✎ Obturator externus – Rotation of thigh on lateral side.
- ✎ Tensor tympani – Connects the malleus to the wall of the tympanic chamber in the ear of mammal.
- ✎ Hilton muscle is aryepiglotticus muscle
- ✎ In children the bone are more flexible and brittle because their bone have large quantity of organic substances and little salt.
- ✎ Hardest tissue in human body – tooth enamel
- ✎ In muscular hypertrophy cells increase in size by synthesizing the length of a myofibril.
- ✎ Presence of furcula in birds.
- ✎ Calcaneal process forms the heal in rabbit.
- ✎ Endoplasmic reticulum or sarcoplasmic reticulum play a major role during muscle contraction, muscle excitement and muscle relaxation.
- ✎ In birds, fore limbs are modified into wings.
- ✎ Skeleton is absent in jelly fish.
- ✎ Urostyle present in caudal region of frog.
- ✎ Tail vertebrae of birds form pygostyle.
- ✎ Birds has pneumatic bone.
- ✎ Six typical vertebrae present in frog.
- ✎ Central shaft of a long bone is known as diaphysis.
- ✎ Curved bone is structurally designed to absorb the stress of the body weight at several different points so that the stress is evenly distributed.
- ✎ Tibio-fibula is the shank bone.
- ✎ Joint between skull and atlas which allows nodding movement is called atlanto-occipital joint.
- ✎ Sphenoid is called as key stone bone of cranial floor, because it articulates with all other cranial bones.
- ✎ Ethmoid bone with cribriform plate with 'crista galli' triangular process. Crista galli serves as point of attachment for meninges that cover the brain
- ✎ The bones common to face and cranium are frontal.
- ✎ Dermatocranium of skull comprises of membranous bone.
- ✎ Coronoid process is a part of lower jaw in mammalian skull.
- ✎ Sella turcica is found in base-sphenoid bone. It is a depression in skull which lodges the pituitary body.
- ✎ Amphibian & mammalia has dicondylic skull and reptiles, birds has monocondylic skull.
- ✎ Alar process is a part of hyoid apparatus.
- ✎ Hammer shaped bone in skull of frog is squamosal
- ✎ Rigor mortis – It is the state of body stiffening after death due to non separation of actin and myosin filaments caused by non-availability of ATP
- ✎ Cori's cycle – It is the passage of lactic acid produced in muscles into liver where 80% of it is changed to glucose/glycogen for continued supply to muscles. The remaining is oxidised.

## Tips & Tricks

- ✎ Calf muscle – Gastrocnemius (Shank muscle).
- ✎ Trijection muscle – Deltoid muscle.
- ✎ Hamstring muscle – Semi tendinosus, semi membranous, biceps femoris. In players there is very common over stretching of these muscle.
- ✎ Flying muscle – Pectoralis major and minor
- ✎ Strongest muscle – Jaw muscle (Masseter).
- ✎ Smiling muscle – Buccalis
- ✎ Fastest muscle – Muscles of upper eye lid
- ✎ Sartorius muscle – Flexion of thigh, knee and its rotation

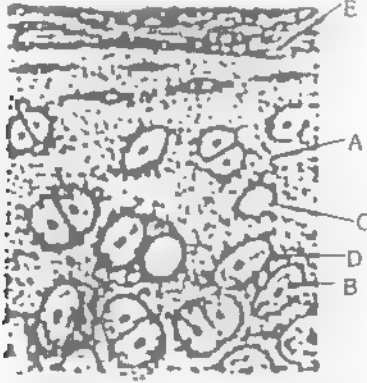


## Ordinary Thinking

## Objective Questions

## Axial skeleton

- Bone marrow is largely composed of [CBSE PMT 1990]
  - Periosteum and osteoblast
  - Adipose tissue and blood vessels
  - Yellow and elastic tissue
  - Cartilage and elastic tissue
- The collar bone is known as [MP PMT 2012]
  - Scapula
  - Coracoid
  - Stapes
  - Clavicle
- The bony sockets of the jaws in which the teeth are implanted, are known as
  - Alveolus
  - Fossae
  - Dentaries
  - Thecae
- The type of vertebrae in sub-order ophidia is [Pb. PMT 1999]
  - Amphicoelous
  - Acoelous
  - Heterocoelous
  - Procoelous
- Number of cranial nerves in mammal are [RPMT 1995; KCET 2000; Odisha JEE 2008]
  - 10 pairs
  - 8 pairs
  - 12 pairs
  - 16 pairs
- Nucleus pulposus is [AFMC 2004]
  - A type of special cell found in myelin sheath of a nerve cell of vertebrate
  - A depression for pituitary is found in mammalian skull
  - A large nucleus found in Schwann cells of nerve fibre
  - A remain of embryonic notochord found in the central portion of inter-vertebral discs of vertebrae of mammals
- The first vertebra, the atlas by its articulation with axis vertebra facilitates a
  - Noding movement
  - Sideway movement
  - Rotatory movement
  - Backward movement
- The vertebrae in which centrum is absent and transverse process are present is known as
  - Lumber vertebrae
  - Anterior thoracic
  - Axis vertebrae
  - Atlas vertebrae
- The number of vertebrae present in cervical, thoracic, lumbar, sacral and coccyx regions respectively are [NCERT; MH CET 2000; BHU 2001; Kerala PMT 2003, 06; HP PMT 2005; Odisha JEE 2008; AFMC 2008]
  - 12, 7, 5, 1, 1
  - 1, 7, 5, 12, 1
  - 7, 5, 1, 12, 1
  - 7, 12, 5, 1, 1
  - 5, 12, 7, 1, 1
- Which one of the following items gives its correct total number [CBSE PMT 2008]
  - Types of diabetes – 3
  - Cervical vertebrae in humans – 8
  - Floating ribs in humans – 4
  - Amino acids found in proteins – 16
- Find out the correct order of number of bones in the parts of skull such as cranial bone, facial bone, hyoid bone and middle ear bone respectively [Kerala PMT 2007]
  - 14, 8, 1 and 6
  - 6, 8, 14 and 1
  - 14, 8, 6 and 1
  - 8, 6, 14 and 1
  - 8, 14, 1 and 6
- The number of vertebrae in rabbit is
  - 40
  - 33
  - 44
  - 46
- Lumbar vertebra are found in [CPMT 2005]
  - Neck region
  - Abdominal region
  - Hip region
  - Thorax
- The skull of a bird is [Pb. PMT 1999]
  - Dicondylic
  - Monocondylic
  - Amphicondylic
  - None of these
- The opening at the base of the skull for the spinal cord is called [CMC Vellore 1993; RPMT 1995; CPMT 2010]
  - Foramen Magnum
  - Foramen of Monro
  - Obturator foramen
  - Foramen of Magendie
- The 8th and 9th ribs are known as false ribs because their external portions are attached to [CPMT 1992]
  - Xiphisternum
  - Costa of 7<sup>th</sup> rib
  - They have no costa
  - They are not true ribs
- Which one is not cranial bone [GUJCET 2015]
  - Frontal
  - Zygomatic
  - Temporal
  - Sphenoid
- Thoracic cage in rabbit is made up of [CPMT 2009]
  - Ribs, vertebral column and diaphragm
  - Ribs, diaphragm and sternum
  - Vertebral column, diaphragm and sternum
  - Ribs, vertebral column & sternum
- In the pelvic girdle of man A, B, C, D and E respectively represents [Kerala PMT 2008]
 
  - A – pubis, B – acetabulum, C – ilium, D – ischium, E – pubic symphysis
  - A – ilium, B – acetabulum, C – pubis, D – ischium, E – pubic symphysis
  - A – ischium, B – acetabulum, C – pubis, D – ilium, E – pubic symphysis
  - A – ilium, B – pubis, C – acetabulum, D – pubic symphysis, E – ischium
  - A – ilium, B – acetabulum, C – pubic symphysis, D – ischium, E – pubis
- The vertebrae in birds are mostly [CBSE PMT 2000; MH CET 2001]
  - Procoelous
  - Amphicoelous
  - Opisthocoelous
  - Heterocoelous
- Vertebral formula for human beings is [Kerala PMT 2006]
  - $C_5T_{12}L_7S_5C_{3-5} = 33-35$
  - $C_7T_{12}L_5S_5C_{3-5} = 33-35$
  - $C_5T_{10}L_5S_5C_{3-5} = 33$
  - $C_7T_{10}L_5S_5C_{3-5} = 33$
- Centrum of man is
  - Procoelus
  - Amphicoelus
  - Amphiplateus
  - Ophisthocoelus

23. Long neck of camel is due to [BHU 1995; CPMT 1995]  
 (a) Increase in length of cervical vertebra  
 (b) Due to bony plate between two vertebra  
 (c) Due to muscle in between two vertebra  
 (d) None of the above
24. Sella turcica is a  
 (a) Covering of kidney  
 (b) Covering of testis  
 (c) Depression in brain  
 (d) Depression in skull which lodges the pituitary body
25. In which bone the chondrocytes are replaced by osteocytes  
 (a) Maxilla (b) Nasal  
 (c) Dentary (d) Vomer
26. Which one of the following is the correct description of a certain part of a normal human skeleton [CBSE PMT (Mains) 2010]  
 (a) Parietal bone and the temporal bone of the skull are joined by fibrous joint  
 (b) First vertebra is axis which articulates with the occipital condyles  
 (c) The 9<sup>th</sup> and 10<sup>th</sup> pairs of ribs are called the floating ribs  
 (d) Glenoid cavity is a depression to which the thigh bone articulates
27. The number of floating ribs in human body is [CBSE PMT 1995, 2007; AFMC 2000]  
 (a) 6 pairs (b) 3 pairs  
 (c) 5 pairs (d) 2 pairs
28. Centrum of 8<sup>th</sup> vertebra of frog is [DUMET 2009]  
 (a) Amphiplatyon (b) Procoelous  
 (c) Amphicoelous (d) Opisthocoelous
29. In the first two or three lumbar vertebrae there is a small median process below the centrum, this is called  
 (a) Pre-zygapophysis (b) Post-zygapophysis  
 (c) Hypapophysis (d) Neural spine
30. In the diagram of section of Hyaline cartilage, the different parts have been indicated by alphabets; choose the answer in which these alphabets correctly match with the parts they indicate [KCET 2004]
- 
- (a) A = perichondrium B = Chondrocyte  
 C = Lacuna D = Capsular matrix  
 E = Chondrin
- (b) A = Capsular matrix B = Chondrocyte  
 C = Lacuna D = Perichondrium  
 E = Chondrin
- (c) A = Chondrin B = Chondrocyte  
 C = Lacuna D = Capsular matrix  
 E = Perichondrium
- (d) A = Chondrin B = Lacuna  
 C = Chondrocyte D = Capsular matrix  
 E = Perichondrium
31. Bone related to skull is [CBSE PMT 2000]  
 (a) Atlas (b) Caracoid  
 (c) Artenoid (d) Pterygoid
32. What is correct about human body [MP PMT 1993]  
 (a) There are 5 vertebra in the neck  
 (b) Brain box is made up of 4 bones  
 (c) There are 15 pairs of ribs  
 (d) There are 12 thoracic vertebra
33. In mammals (rabbit), the zygomatic arch is formed by [CPMT 1998]  
 (a) Maxilla, premaxilla and squamosal  
 (b) Periotic, jugal and palatine  
 (c) Maxilla, squamosal and jugal  
 (d) Jugal, maxilla and periotic
34. A vertebra has a convexity both in front and behind it. It is called [AFMC 1997; MH CET 2002; BHU 2012]  
 (a) Procoelous (b) Amphicoelous  
 (c) Acoelous (d) Amphiplatyon
35. The last two pairs of ribs are named floating ribs because  
 (a) Their sternal parts are attached to the sternum directly  
 (b) Their sternal parts are attached on the 7<sup>th</sup> pair of ribs  
 (c) Their sternal parts remain free and do not even reach the sternum  
 (d) They float in the body cavity
36. Special fibrous joint occurring exclusively in skull which is the tightest type of joint is [NCERT; CBSE PMT 1993]  
 (a) Suspensorium (b) Suspensory ligament  
 (c) Suture (d) Occipital
37. The vertebrae which bears the whole weight of the skull is [CBSE PMT 1993]  
 (a) Axis (b) Sacral  
 (c) Cervical (d) Atlas
38. The parasphenoid bone in frog forms [CPMT 2004]  
 (a) Base of cranium  
 (b) Floor of cranium  
 (c) Dorsal side of cranium  
 (d) Dorsolateral side of cranium
39. How many ribs are present in human beings [CPMT 1994; HP PMT 2005]  
 (a) 6 pairs (b) 9 pairs  
 (c) 12 pairs (d) 15 pairs
40. Axis vertebra of a mammal differs from atlas in [CPMT 1993; MP PMT 1994]  
 (a) Absence of centrum  
 (b) Presence of centrum  
 (c) Presence of central canal  
 (d) Presence of odontoid process
41. Number of bones in skull is [MP PMT 2007]  
 (a) 26 (b) 28  
 (c) 107 (d) 29
42. In human beings the cranium is formed by [AIIMS 2000; MHCET 2000; AMU (Med.) 2010]  
 (a) Eight bones of which two are paired  
 (b) Fourteen bones of which six are paired  
 (c) Ten bones of which two are paired  
 (d) Twelve bones of which four are paired
43. Which of the following is unpaired bone  
 (a) Premaxilla (b) Pro-otics  
 (c) Sphenethmoid (d) Pterygoid
44. In man the axial skeleton is made up of  
 (a) 80 bones (b) 100 bones  
 (c) 103 bones (d) 106 bones

45. The number of bones in half of the lower jaw of man is  
(a) 1 (b) 4  
(c) 6 (d) 8
46. In man the thoracic basket is composed of  
[MP PMT 2002, 06]  
(a) Ribs and thoracic vertebrae  
(b) Ribs and sternum  
(c) Ribs, sternum and vertebrae  
(d) Ribs, sternum and thoracic vertebrae
47. Innominate is a [CPMT 2009]  
(a) Nerve  
(b) Muscle  
(c) Animal  
(d) A Part of skeleton and an artery
48. Tongue bone is  
(a) Hyoid bone (b) Maxillary  
(c) Dentary (d) Quadrato-jugal
49. Human vertebral column consists of 33 vertebrae and \_\_\_\_\_ bones [CPMT 1992; BHU 2012]  
(a) 33 (b) 26  
(c) 27 (d) 29
50. Cervical vertebrae are located in [HP PMT 2005]  
(a) Thoracic region (b) Abdominal region  
(c) Neck region (d) Lumbar region
51. The number of cervical vertebrae in camels is [CBSE PMT 2002]  
(a) Same as that in rabbit (b) Same as that in frog  
(c) Less than that in giraffe (d) More than that in horse
52. The major function of the intervertebral discs is to [DUMET 2010]  
(a) Absorb shock  
(b) String the vertebrae together  
(c) Prevent injuries  
(d) Prevent hyperextension
53. Out of 'X' pairs of ribs in humans only 'Y' pairs are true ribs. Select the option that correctly represents values of X and Y and provides their explanation [NEET 2017]

(a)	X=12, Y=7	True ribs are attached dorsally to vertebral column and ventrally to the sternum
(b)	X=12, Y=5	True ribs are attached dorsally to vertebral column and sternum on the two ends
(c)	X=24, Y=7	True ribs are dorsally attached to vertebral column but are free on ventral side
(d)	X=24, Y=12	True ribs are dorsally attached to vertebral column but are free on ventral side

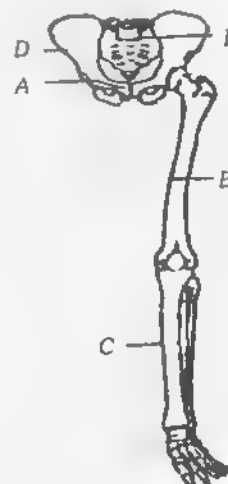
### Appendicular skeleton

1. In rabbit radius and ulna are [MP PMT 1992]  
(a) Completely fused together  
(b) Completely separated  
(c) Fused in middle and separated at both the ends  
(d) Separated but united at both the ends

2. A shallow depression in the scapula which receives the head of the upper arm bone is known as the [NCERT; CBSE PMT 1993; AIPMT (Cancelled) 2015]

Or

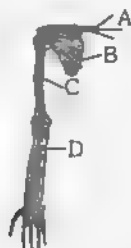
- Which one of the following component is the part of pectoral girdle [CBSE PMT 1994; MP PMT 1994; DPMT 2007]  
(a) Acetabulum (b) Neural arch  
(c) Glenoid cavity (d) None of the above
3. Patella, the knee cap is the example of [NCERT; MP PMT 1996, 2007; BVP 2001; AIIMS 2003; Pb. PMT 2004]  
(a) Cartilage gland (b) Replacing bone  
(c) Sesamoid bone (d) None of the above
4. The protein present in the bones is known as [CBSE PMT 1992]  
(a) Chondrin (b) Ossein  
(c) Sclero protein (d) Globulin
5. Humerus bone is situated in  
(a) Thigh (b) Lower arm  
(c) Upper arm (d) Shank
6. Consider the diagram given below [Kerala PMT 2006]



Parts labelled as 'A', 'B', 'C', 'D', and 'E' respectively indicate

- (a) Femur, Ilium, Tibia, Pubis and Sacrum  
(b) Pubis, Tibia, Femur, Ilium and Sacrum  
(c) Ilium, Femur, Tibia, Pubis and Sacrum  
(d) Tibia, Pubis, Femur, Ilium and Sacrum  
(e) Pubis, Femur, Tibia, Ilium and Sacrum
7. Symphysis contains [AFMC 2012]  
(a) Hyaline cartilage  
(b) Fibrous cartilage  
(c) Calcified cartilage  
(d) None of these
8. Outer covering of cartilage is [DPMT 1993; WB JEE 2010]  
(a) Perichondrium (b) Periosteum  
(c) Endo-osteum (d) Peritonium

9. Which option is correct for the region labelled as a, b, c and d in the given diagram  
[NCERT; GUJCET 2014]



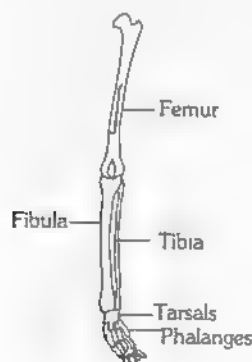
- (a) A – Clavicle, B – Scapula, C – Humerus, D – Ulna  
(b) A – Scapula, B – Clavicle, C – Humerus, D – Ulna  
(c) A – Clavicle, B – Ulna, C – Radius, D – Humerus  
(d) A – Clavicle, B – Glenoid cavity, C – Radius, D – Ulna
10. The longest bone of the human body is  
[NCERT; Kerala PMT 2009]
- (a) Humerus (b) Tibia  
(c) Vertebra (d) Femur  
(e) Incus
11. Olecranon fossa is present over  
[MH CET 2004]
- (a) Scapula (b) Ulna  
(c) Radius (d) Humerus
12. Synsacrum of fowl is consist of about  
[BHU 2004]
- (a) 29 vertebrae (b) 3 vertebrae  
(c) 16 vertebrae (d) Single vertebrae
13. The pelvic girdle of birds is attached to a complex structure formed by the fusion of last thoracic, all lumbar and first five caudal vertebra. This structure is called  
[MP PMT 1993]

Or

In birds, some of the vertebrae are fused to form

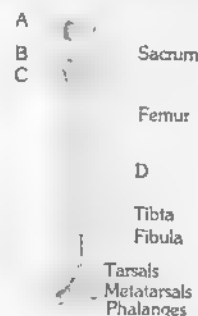
[MHCET 2001; CBSE PMT 2001]

- (a) Synsacrum (b) Symphysis  
(c) Synkaryon (d) Sympelvis
14. Given below is a diagram of the left human hindlimb as seen from front. It has certain mistakes in labeling. Two of the wrongly labelled bones are  
[AIIMS 2005]



- (a) Tibia and tarsals (b) Femur and fibula  
(c) Fibula and phalanges (d) Tarsals and femur

15. Consider the following diagram. Identify A, B, C and D  
[NCERT]



- (a) A – Ilium, B – Pubis, C – Ischium, D – Patella  
(b) A – Ilium, B – Pubis, C – Patella, D – Ischium  
(c) A – Ischium, B – Pubis, C – Ilium, D – Patella  
(d) A – Pubis, B – Ilium, C – Ischium, D – Patella
16. Choose the correct option regarding a normal human
- A. The skull is dicondylic  
B. Metacarpals are five in numbers  
C. Patella is a cup-shaped bone covering the knee dorsally  
D. Scapula is a large triangular flat bone, situated on the ventral side of the thorax  
E. The pelvic girdle has two coxal bones
- [Kerala PMT 2012]
- (a) A and E alone are wrong (b) A and B alone are wrong  
(c) B and E alone are wrong (d) C and D alone are wrong  
(e) E alone is wrong
17. The pectoral and pelvic girdles and the bones of limb form  
[DPMT 1993; MHCET 2000]
- (a) Axial skeleton (b) Appendicular skeleton  
(c) Visceral skeleton (d) Outer skeleton
18. What will happen if a bone is kept in 10% KOH solution for 3 days
- (a) Remain unchanged (b) Dissolved  
(c) Become soft and elastic (d) Break
19. The canal seen in the bone of mammals are  
[AFMC 1993]
- (a) Haversian canals only  
(b) Volkmann's canals only  
(c) Haversian and Volkmann's canals  
(d) Canal of Schlemm
20. Number of bones in human body is  
[NCERT; CMC Vellore 1993; Pb. PMT 2000; JIPMER 2002]
- (a) 260 (b) 206  
(c) 306 (d) 203
21. The total number of bones in your right arm is  
[NCERT; AFMC 2004]

Or

Total number of bones in the hind limb of a man is

[NCERT; CBSE PMT 1998]

- (a) 30 (b) 32  
(c) 35 (d) 40

22. Scapula is a large triangular flat bone situated in the dorsal part of the thorax between [Kerala PMT 2011]  
 (a) The second and fifth ribs  
 (b) The second and seventh ribs  
 (c) The third and sixth ribs  
 (d) The third and eighth ribs  
 (e) The fourth and seventh ribs
23. An acromian process is characteristically found in rabbit/mammals in [NCERT; MP PMT 1994, 95; CBSE PMT 2005]  
 (a) Pelvic girdle (b) Pectoral girdle  
 (c) Skull (d) Sternum
24. The matrix of bone and cartilage can be distinguished by the presence of [Odisha JEE 2010]  
 (a) Haversian canal (b) Lacuna  
 (c) Chromatophores (d) Adipose cells
25. What is the difference between the bone of rabbit and that of frog [CPMT 1996]  
 (a) In the bone of rabbit haversian canal is found  
 (b) Yellow marrow is found  
 (c) Osteocytes are of different types  
 (d) Bone of frog is spongy
26. Acetabulum is present in [NCERT; CPMT 2010]  
 (a) Pelvic girdle of rabbit (b) Pectoral girdle of rabbit  
 (c) Both (a) and (b) (d) None of these
27. Ends of long bones are covered with [MP PMT 1994]  
 (a) Cartilage (b) Muscles  
 (c) Ligaments (d) Blood cells
28. Olecranon process is found in [MP PMT 1994]  
 (a) Proximal end of ulna (b) Distal end of ulna  
 (c) Proximal end of tibia (d) Proximal end of humerus
29. Which of the following is absent in the segment of cockroach's leg [DPMT 2004]  
 (a) Fibula (b) Coxa  
 (c) Tibia (d) Femur
30. Three of the following pairs of the human skeletal parts are correctly matched with their respective inclusive skeletal category and one pair is not matched. Identify the non-matching pair [CBSE PMT (Malna) 2011]
- | Pairs of skeletal parts         | Category              |
|---------------------------------|-----------------------|
| (a) Humerus and ulna            | Appendicular skeleton |
| (b) Malleus and stapes          | Ear ossicles          |
| (c) Sternum and Ribs            | Axial skeleton        |
| (d) Clavicle and Glenoid cavity | Pelvic girdle         |
31. Astragalus and calcaneum are present in [Pb. PMT 1999; AIIMS 2001]  
 (a) Fore limb (b) Hind limb  
 (c) Scapula (d) Clavicle
32. Deltoid ridge is found in which one of the following bones [RPMT 1999, 2005; CPMT 2002; DPMT 2004]  
 (a) Radius (b) Tibia  
 (c) Femur (d) Humerus
33. Pelvic girdle of rabbit consist of [NCERT; CPMT 2002; RPMT 2005]  
 Or  
 The coxal of the pelvic girdle is formed by the fusion of [CBSE PMT 2009; Kerala PMT 2011]  
 Or  
 In mammals, each half of pelvic girdle or obturator foramen in pelvic girdle is formed by [MP PMT 1998, 2013; PET Pharmacy 2013]  
 (a) Ilium, ischium and pubis  
 (b) Ilium, ischium and coracoid  
 (c) Coracoid, scapula and clavicle  
 (d) Ilium, coracoid and scapula
34. Pectoral girdle constitute [AFMC 2010]  
 (a) Scapula and Clavicle  
 (b) Radius and Ulna  
 (c) Ilium and Ischium  
 (d) Maxilla and mandible
35. The sigmoid notch is present in  
 (a) Femur (b) Tibio-fibula  
 (c) Humerus (d) Ulna
36. Presence of furcula is a characteristic feature of  
 (a) Frogs (b) Reptiles  
 (c) Birds (d) Mammals
37. In children the bones are more flexible and brittle because their bones have  
 (a) Large quantity of salts and little organic substances  
 (b) Large quantity of organic substances and little salts  
 (c) Well developed Haversian system  
 (d) Large number of osteoblasts
38. Ankle bones have 6 tarsals and arranged in three rows then 1st row have [CPMT 1994]  
 (a) Astragalus and calcaneum  
 (b) Pterygoid and astragalus  
 (c) Pterygoid and calcaneum  
 (d) None of these
39. Triceps muscle joins ulna with  
 (a) Radius (b) Humerus  
 (c) Phallanges (d) Suprascapula
40. In mammals each half of pectoral girdle consists of [MP PMT 1998]  
 (a) Supra scapula (b) Scapula  
 (c) Coracoid (d) All the above
41. Innominate or hip bone is formed by the fusion of how many bones [NCERT]  
 (a) 2 (b) 3  
 (c) 4 (d) 5



42. Haversian canals are found in  
[AFMC 1997; MP PMT 1997, 2012; BHU 2000;  
DPMT 2003; MHCET 2003; BVP 2004; CPMT 2010]

(a) Spinal cord (b) Brain  
(c) Long bones (d) Sponge

43. Phalangeal formula of hand of man is [NCERT]

(a) 1, 2, 2, 2, 2 (b) 2, 1, 1, 1, 1  
(c) 2, 3, 3, 3, 3 (d) 2, 3, 3, 2, 2

44. Structure responsible for formation of sigmoid notch is  
[CPMT 2005]

(a) Olecranon process of humerus  
(b) Olecranon process of femur  
(c) Olecranon process of radius ulna  
(d) Olecranon process of tibia fibula

45. Old people are, more liable to fracture of their bones because

(a) Bones become soft and elastic  
(b) Bones become hard and brittle  
(c) Bones contain large quantity of organic matter  
(d) None of the above

### Joints

1. The gliding joints are important for gliding movements. One example of such a joint is between the

[MP PMT 1992; BVP 2003]

(a) Zygapophysis of adjacent vertebrae  
(b) Humerus and the glenoid cavity  
(c) Occipital condyle and odontoid process  
(d) Femur and tibio-fibula

2. An example of synovial joint is found between

[MP PMT 1992]

(a) Two vertebrae (b) Two skull bones  
(c) Humerus and ulna (d) Tail vertebrae

3. The example of pivot joint is [DUMET 2010]

(a) Hip joints  
(b) Metacarpophalangeal joints  
(c) Ankle joints  
(d) Radioulnar joints

4. Elbow joint is an example of [CBSE PMT 2009]

(a) Pivot joint  
(b) Hinge joint  
(c) Gliding joint  
(d) Ball and socket joint

5. Hinge joint is present between [DPMT 1993;  
CPMT 1994, 96; MP PMT 1994, 2006, 07, 12;  
BHU 2000; MH CET 2003; Pb. PMT 2004]

(a) Humerus and pectoral girdle  
(b) Femur and acetabulum  
(c) Humerus and radio-ulna  
(d) Femur and pelvic girdle

6. Match the following and choose the correct option

Types of synovial joints		Bones involved	
A.	Ball and socket	1.	Carpal and metacarpal of thumb
B.	Hinge	2.	Atlas and axis
C.	Pivot	3.	Frontal and parietal
D.	Saddle	4.	Knee
		5.	Humerus and pectoral girdle

[NCERT; CBSE PMT 1999; Kerala PMT 2010;  
Odisha JEE 2010]

(a) A-5, B-4, C-2, D-1 (b) A-1, B-3, C-4, D-5  
(c) A-5, B-4, C-3, D-1 (d) A-1, B-2, C-5, D-4  
(e) A-2, B-5, C-4, D-1

7. The joint between the lower jaw and the skull is

(a) Gliding (b) Hinge  
(c) Perfect joint (d) Saddle joint

8. Ball and socket joints can be seen in

[MP PMT 1993; J & K CET 2002; Odisha JEE 2011]

(a) Wrist (b) Fingers  
(c) Neck (d) Shoulders

9. The type of joint between the human skull bones is

[CBSE PMT 1994; BHU 1999]

(a) Synarthrodial joint (b) Synovial joint  
(c) Cartilaginous joint (d) Fibrous joint

10. Which cartilage is present at the joints of long bones

[MP PMT 1998; CBSE PMT 2002; CPMT 2009]

(a) Calcified (b) Hyaline  
(c) Elastic (d) Fibrous

11. Which one of the following pairs of structures is correctly matched with their correct description

[CBSE PMT (Maine) 2010]

Structures Description

(a) Tibia and fibula Both form parts of knee joint  
(b) Cartilage and cornea No blood supply but do require oxygen for respiratory need  
(c) Shoulder joint and elbow joint Ball and socket type of joint  
(d) Premolars and molars 20 in all and 3—rooted

12. When the head of humerus fits into glenoid cavity, joint is

(a) Ball and socket joint (b) Hinge joint  
(c) Pivot joint (d) Saddle joint

13. An all out sprint can not continue for more than 40 seconds because [Odisha JEE 2004]

(a) Run out of oxygen (b) Accumulation of creatine  
(c) Muscles collapse (d) All of these

14. Select the correct matching of the type of the joint with the example in human skeletal system

[MP PMT 2003; CBSE PMT 2014]

Type of joint	Example
(a) Hinge joint	- Between humerus and pectoral girdle
(b) Gliding joint	- Between carpals
(c) Cartilaginous joint	- Between frontal and parietal
(d) Pivot joint	- Between third and fourth cervical vertebrae

15. Which of the following joints would allow no movement

[AIPMT 2015]

- (a) Cartilaginous joint (b) Synovial joint  
(c) Ball and socket joint (d) Fibrous joint

16. The ankle, knee and elbow joints are

[NCERT; DPMT 2006; J & K CET 2010]

- (a) Synovial joints (b) Hinge joints  
(c) Pivot joints (d) Ellipsoid joints

17. Joint between femur and pelvic girdle is

[CPMT 1995; CBSE PMT 2001; MH CET 2003]

Or

Joint between femur and acetabulum is known as

[CPMT 1996]

- (a) Pivotal (b) Ball and socket  
(c) Hinge (d) Saddle

18. Achilles tendon is associated with

[BHU 2004]

- (a) Gluteus muscle (b) Hamstring muscle  
(c) Quadriceps muscle (d) Gastrocnemius muscle

19. Joint between femur and tibio-fibula is

[CPMT 1996]

- (a) Hinge joint (b) Saddle joint  
(c) Pivot joint (d) Imperfect joint

20. ....acts as a shock absorber to cushion when tibia and femur came together

[Odisha JEE 2005]

- (a) Ligament (b) Cartilage  
(c) Tendon (d) Disc

21. The end of long bones are connected to each other by

[CPMT 1992, 93, 98, 2000, 2003; DPMT 1993;  
MP PMT 1994, 97, 2001, 06; AFMC 1997, 2005;  
RPMT 1999; J & K CET 2002; BHU 2006]

- (a) Muscles (b) Tendons  
(c) Ligaments (d) Cartilage

22. Joint between ribs and sternum is

[CBSE PMT 2000]

- (a) Cartilaginous (b) Angular joint  
(c) Fibrous joint (d) Gliding joint

23. Sutural joints are found between

[MP PMT 2000]

- (a) Parietals of skull  
(b) Humerus and radio-ulna  
(c) Glenoid cavity and pectoral girdle  
(d) Thumb and metatarsal

24. Which of the following pairs, is correctly matched

[CBSE PMT 2005]

- (a) Hinge joint - Between vertebrae  
(b) Gliding joint - Between zygapophyses of the successive vertebrae  
(c) Cartilaginous joint - Skull bones  
(d) Fibrous joint - Between phalanges

25. Tendon is a structure which connects

[DPMT 1992; CPMT 1993;

MP PMT 1999, 2004, 11; BVP 2001; MHCET 2004]

- (a) A bone with another bone  
(b) A nerve with a muscle  
(c) A muscle with a bone  
(d) A muscle with a muscle

26. Synovial joints is

[Odisha JEE 2004]

- (a) Pivot joint (b) Hinge joint  
(c) Ball and socket joint (d) All of these

27. The pivot joint between atlas and axis is a type of

[NEET 2017]

- (a) Fibrous joint (b) Cartilaginous joint  
(c) Synovial joint (d) Saddle joint

## Muscles

1. Sarcolemma is a membrane found over in

[MP PMT 1994]

- (a) Nerve fibre (b) Cardiac muscle  
(c) Skeletal muscle fibre (d) Heart

2. Ensheathing of muscles is called

[CPMT 1999; JIMPER 2001]

- (a) Fascia (b) Peritoneum  
(c) Ligament (d) Tendon

3. Standing on tip toe is an example of

[DUMET 2009]

- (a) Elevation (b) Flexion  
(c) Extension (d) Retraction

4. Action potential in a muscle fibre is

- (a) -90 mV (b) -80 mV  
(c) 45-50 mV (d) 90 mV

5. The generation of excitation-contraction coupling involves all the following events except

[WB JEE 2009]

- (a) Generation of end-plate potential  
(b) Release of calcium from troponin  
(c) Formation of cross-linkages between actin and myosin  
(d) Hydrolysis of ATP to ADP

6. See the figure of actin (thin) filaments. Identify A, B and C

[NCERT]



- (a) A - Troponin, B - Tropomyosin, C - F - actin  
(b) A - Troponin, B - Tropomyosin, C - Myosin  
(c) A - Troponin, B - Myosin, C - F - Tropomyosin  
(d) A - Tropomyosin, B - Troponin, C - F - actin

7. The contraction of muscle of shortest duration is seen in

- (a) Heart (b) Jaws  
(c) Intestine (d) Eyelids

8. 'Gastrocnemius' is a muscle of

- (a) Forelimbs (b) Thigh  
(c) Shank (d) Abdomen of frog

9. ATPase enzyme needed for muscle contraction is located in

[CBSE PMT 2004]

Or

The contractile protein of skeletal muscle involving ATPase activity is

[CBSE PMT 1998; 2006]

- (a) Myosin (b) Actin  
(c) Actinin (d) Troponin

10. Select the letter from the figure that most appropriately corresponds to the structure



- I. A - band  
III. Sarcomere  
V. Myosin  
VI. Actin, Troponin, Tropomyosin  
VII. Z- line
- II. I - band  
IV. H - zone
- [NCERT]
- (a) I - E, II - D, III - F, IV - A, V - B, VI - C, VII - G  
(b) I - E, II - D, III - F, IV - G, V - C, VI - A, VII - B  
(c) I - E, II - D, III - C, IV - G, V - B, VI - A, VII - F  
(d) I - E, II - D, III - F, IV - G, V - B, VI - C, VII - A
11. What is sprain [AIIMS 1993; BHU 1995]  
(a) More pulling of tendon (b) Less pulling of tendon  
(c) More pulling of ligament (d) Less pulling of ligament
12. Muscles are red because of the presence of  
(a) Myoglobin and mitochondria  
(b) Haemoglobin and golgi bodies  
(c) Globulin and mitochondria  
(d) Protein and lysosome
13. The dark bands in a myofibril are due to overlapping of  
(a) Only thick bands  
(b) Only thin bands  
(c) Both thick and thin bands  
(d) None of the above
14. The muscle fatigue occurs due to accumulation of [CPMT 1995; Manipal 2005; Wardha 2005]  
(a) Pyruvic acid (b) ATP  
(c) Lactic acid (d) Eroman CO<sub>2</sub>
15. The muscular contraction in which the tension remains the same and the mechanical work is also done is called  
(a) Isotonic contraction  
(b) Tetanus  
(c) Isomeric contraction  
(d) Single muscle twitch
16. In a relaxed fibril, H-zone, a lighter region of low density can be seen in the centre of  
Or  
The dark bands (Black bands) of a skeletal muscle are known as  
(a) Anisotropic or A-band (b) Isotropic or I-band  
(c) Z-band (d) Both in A and I-band
17. The total number of muscles in the body of man is  
(a) 409 (b) 439  
(c) 539 (d) 639
18. Major protein in the thick filament of skeletal muscle fibre is [MP PMT 2011]  
(a) Tropomyosin (b) Myosin  
(c) Actin (d) Troponin

19. Select the correct statement with respect to disorders of muscles in humans [NEET (Karnataka) 2013]

- (a) Failure of neuromuscular transmission in myasthenia gravis can prevent normal swallowing  
(b) Accumulation of urea and creatine in the joints cause their inflammation  
(c) An overdose of vitamin D causes osteoporosis  
(d) Rapid contractions of skeletal muscles causes muscle dystrophy

20. Largest number of muscles will be found in [MP PMT 1993]

- (a) Head (b) Neck  
(c) Back (d) Arm

21. Muscles of the heart are [NCERT; WB JEE 2011]

- (a) Voluntary, striated (b) Voluntary, smooth  
(c) Involuntary, striated (d) Involuntary, smooth

22. Cori's cycle operates in

- (a) Liver (b) Liver and muscles  
(c) Nerve (d) Muscles

23. Contraction of a muscle is caused by [MP PMT 1994]

- (a) Myosin (b) Actin  
(c) ATP (d) Actomyosin

24. The biceps and triceps muscles are found in

- (a) Fore arm (b) Shank  
(c) Shoulder (d) Lower jaw

25. For the given statement 'X' and 'Y', which option is the correct option

Statement 'X' - Red muscle are also called aerobic muscle

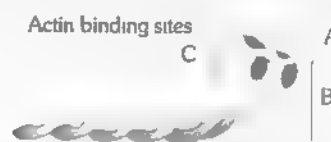
Statement 'Y' - Red muscle possesses large amount of mitochondria which can utilize large amount of oxygen stored in them for ATP production [GUJCET 2014]

- (a) Statement 'X' and 'Y' are correct and statement 'Y' is incorrect explanation for 'X'  
(b) Statement 'X' is correct and 'Y' is incorrect  
(c) Statement 'X' is incorrect and 'Y' is correct  
(d) Statement 'X' and 'Y' are correct and statement 'Y' is correct explanation for 'X'

26. Ciliary muscles are found in

- (a) Diaphragm of a mammal  
(b) Eyes of vertebrates  
(c) Heart of vertebrates  
(d) Stomach of frog

27. The given figure is associated with myosin monomer (meromyosin). Identify A to C [NCERT; KCET 2015]



- (a) A - cross arm, B - head, C - ATP binding sites  
(b) A - head, B - cross arm, C - ATP binding sites  
(c) A - head, B - cross arm, C - Ca<sup>+2</sup> binding sites  
(d) A - head, B - cross arm, C - GTP binding sites

28. Electron microscopic studies of the sarcomeres have revealed that during muscle contraction

[MHCET 2003; KCET 2005; NEET (Karnataka) 2013]

- (a) The width of A-band remains constant
- (b) The width of the H-zone becomes smaller
- (c) The width of I-band increases
- (d) The diameter of the fibre increases

29. Latissimus dorsi muscles are

- (a) Muscles of fore arm
- (b) Muscles of lower jaw
- (c) Muscles of the chest
- (d) Muscles of the shoulder

30. During muscle contraction [AMU (Med.) 2005]

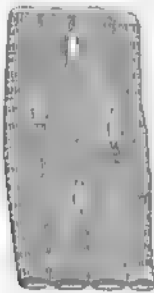
- (a) Chemical energy is changed into electrical energy
- (b) Chemical energy is changed into mechanical energy
- (c) Chemical energy is changed into physical energy
- (d) Mechanical energy is changed into chemical energy

31. The H-zone in the skeletal muscle fibre is due to

[NEET 2013]

- (a) Extension of myosin filaments in the central portion of the A-band
- (b) The absence of myofibrils in the central portion of A-band
- (c) The central gap between myosin filaments in the A-band
- (d) The central gap between actin filaments extending through myosin filaments in the A-band

32. Identify the tissue shown in the diagram and match with its characteristics and its location



[NEET (Karnataka) 2013]

- (a) Smooth muscles, show branching, found in the walls of the heart
- (b) Cardiac muscles, unbranched muscles, found in the walls of the heart
- (c) Striated muscles, tapering at both-ends, attached with the bones of the ribs
- (d) Skeletal muscle, shows striations and closely attached with the bones of the limbs

2. Ribs are attached to

[NCERT]

- (a) Scapula
- (b) Sternum
- (c) Clavicle
- (d) Ilium

3. ATPase of the muscle is located in

[NCERT]

- (a) Actinin
- (b) Troponin
- (b) Myosin
- (d) Actin

4. Intervertebral disc is found in the vertebral column of

[NCERT]

- (a) Birds
- (b) Reptiles
- (c) Mammals
- (d) Amphibians

5. Which one of the following is showing the correct sequential order of vertebrae in the vertebral column of human beings

[NCERT]

- (a) Cervical – lumbar – thoracic – sacral – coccygeal
- (b) Cervical – thoracic – sacral – lumbar – coccygeal
- (c) Cervical – sacral – thoracic – lumbar – coccygeal
- (d) Cervical – thoracic – lumbar – sacral – coccygeal

6. Which one of the following options is incorrect

[NCERT]

- (a) Hinge joint – between Humerus and Pectoral girdle
- (b) Pivot joint – between atlas, axis and occipital condyle
- (c) Gliding joint – between the carpals
- (d) Saddle joint – between carpal and metacarpals of thumb

7. Match the followings and mark the correct option

Column I

Column II

- |                         |                      |
|-------------------------|----------------------|
| A. Sternum              | i. Synovial fluid    |
| B. Glenoid Cavity       | ii. Vertebrae        |
| C. Freely movable joint | iii. Pectoral girdle |
| D. Cartilagenous joint  | iv. Flat bones       |

Options

[NCERT]

- (a) A-ii, B-i, C-iii, D-iv
- (b) A-iv, B-iii, C-i, D-ii
- (c) A-ii, B-i, C-iv, D-iii
- (d) A-iv, B-i, C-ii, D-iii

8. Macrophages and leucocytes exhibit

[NCERT]

- (a) Ciliary movement
- (b) Flagellar movement
- (c) Amoeboid movement
- (d) Gliding movement

9. Which one of the following is not a disorder of bone

[NCERT]

- (a) Arthritis
- (b) Osteoporosis
- (c) Rickets
- (d) Atherosclerosis

10. Which one of the following statement is incorrect

[NCERT]

- (a) Heart muscles are striated and involuntary
- (b) The muscles of hands and legs are striated and voluntary
- (c) The muscles located in the inner walls of alimentary canal are striated and involuntary
- (d) Muscles located in the reproductive tracts are unstriated and involuntary

11. Which one of the following statements is true

[NCERT]

- (a) Head of humerus bone articulates with acetabulum of pectoral girdle
- (b) Head of humerus bone articulates with glenoid cavity of pectoral girdle
- (c) Head of humerus bone articulates with a cavity called acetabulum of pelvic girdle
- (d) Head of humerus bone articulates with a glenoid cavity of pelvic girdle

## NCERT

### Exemplar Questions

1. Match the following and mark the correct option

Column I

Column II

- |                       |                       |
|-----------------------|-----------------------|
| A. Fast muscle fibres | i. Myoglobin          |
| B. Slow muscle fibres | ii. Lactic acid       |
| C. Actin filament     | iii. Contractile unit |
| D. Sarcomere          | iv. I-band            |

Options

[NCERT]

- (a) A-i, B-ii, C-iv, D-iii
- (b) A-ii, B-i, C-iii, D-iv
- (c) A-ii, B-i, C-iv, D-iii
- (d) A-iii, B-ii, C-iv, D-i

# Critical Thinking

## Objective Questions

- Typically all mammals have seven cervical vertebrae except in [CBSE PMT 1990]
  - Elephant
  - Man
  - Kangaroo
  - Sea cow
- The membranous areas between the cranial bones of the foetal skull are called [DUMET 2010]
  - Areolas
  - Foramina
  - Sutures
  - Fontanelle
- Select the correct statement regarding the specific disorder of muscular or skeletal system [NCERT; CBSE PMT (Pre.) 2012]
  - Muscular dystrophy-age related shortening of muscles
  - Osteoporosis-decrease in bone mass and higher chances of fractures with advancing age
  - Myasthenia gravis-auto immune disorder which inhibits sliding of myosin filaments
  - Gout-inflammation of joints due to extra deposition of calcium
- Which of the following is not a function of the skeletal system [AIPMT 2015]
  - Storage of minerals
  - Production of body heat
  - Locomotion
  - Production of erythrocytes
- The zygomatic process in mammals arises from
  - Premaxilla
  - Maxilla
  - Mandible
  - Squamosal
- In frog, the vertebra with an anterior convex surface is [AIIMS 2000; CPMT 2001]
  - Atlas
  - Urostyle
  - 8<sup>th</sup> vertebra
  - 9<sup>th</sup> vertebra
- Epiphyseal discs, which are present at the ends of long bones are responsible for [AIIMS 1993]
  - Bone elongation
  - Growth of thickness of the bone
  - Remodelling the shape of bone
  - Formation of Haversian canal
- A greater trochanter is found in [BHU 2002]
  - Femur
  - Humerus
  - Ulna
  - Radius
- The Paget's disease is caused by [AMU (Med.) 2009]
  - Prolonged deficiency of vitamin D in adults
  - Abnormal bone resorption by abnormal osteoclasts
  - Excess alkaline phosphatase
  - Excess production and abnormal organization of collagen
- Bone is distinguished from the cartilage by the presence of [JIPMER 1993; CPMT 1993, 2002]
  - Collagen
  - Blood vessels
  - Lymph vessels
  - Haversian canals
- Which of the following is not found in birds [AIIMS 1999]
  - Pectoral girdle
  - Pelvic girdle
  - Hind limb
  - Fore limb
- Interphalangeal joints are also called as
  - Fixed joints
  - Hinge joints
  - Movable joints
  - Straight joints

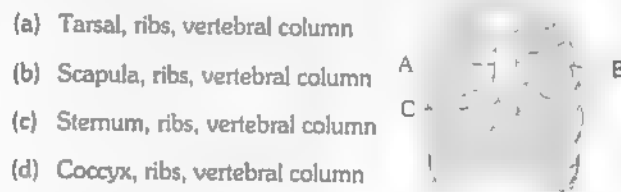
- The immediate regeneration of ATP used up during muscle contraction is facilitated by [AIIMS 1992]
  - Glucose
  - Glycogen
  - Lactic acid
  - Creatine phosphate
- Smallest muscle in the human body [JIPMER 2002]
  - Sartorius
  - Spinal muscle
  - Stapes
  - Stapedius
- Quadriceps and Gastrocnemius muscle lies in [MP PMT 2001]
  - Hands
  - Legs
  - Shoulder
  - Wrist
- See the following figure describing muscle contraction



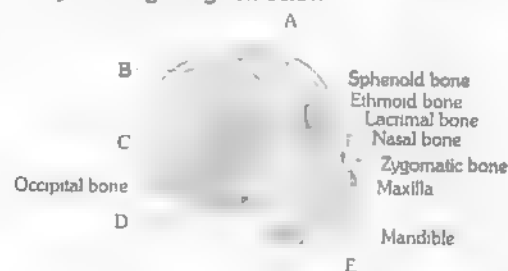
Identify A, B, C, D and E

[NCERT]

- A - Cross bridge, B - Cross bridge formation, C - Sliding/ rotation, D - ADP, E - Breaking of cross bridge
  - A - Cross bridge, B - Breaking of cross bridge, C - Sliding/ rotation, D - Cross bridge formation, E - AMP
  - A - Cross bridge, B - Cross bridge formation, C - Sliding/ rotation, D - Breaking of cross bridge, E - ATP
  - A - Cross bridge, B - Cross bridge formation, C - Breaking of cross bridge, D - Sliding (rotation), E - ATP
- The given figure represents rib cage. Identify A, B and C respectively [NCERT]



- Study the diagram given below

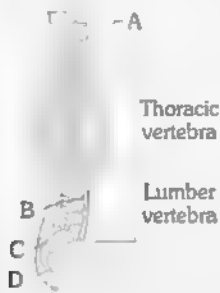


Parts labelled as A, B, C, D and E respectively represent

[NCERT]

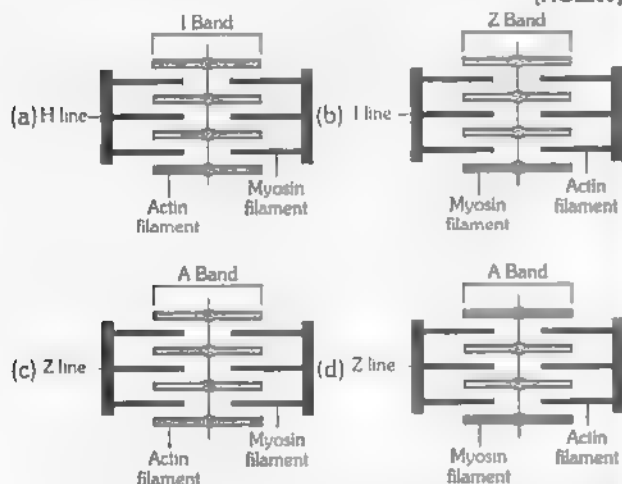
- Parietal bone, Frontal bone, Temporal bone, Occipital condyle and Hyoid bone
- Frontal bone, Parietal bone, Temporal bone, Hyoid bone and Occipital condyle
- Frontal bone, Temporal bone, Parietal bone, Occipital condyle and Hyoid bone
- Frontal bone, Parietal bone, Temporal bone, Occipital condyle and Hyoid bone

19. The given figure indicates vertebral column of human (right lateral view). Parts labelled as A, B, C and D respectively represent [NCERT]



- (a) Cervical vertebra, Intervertebral disc, Sacrum and Lumbar vertebra  
 (b) Cervical vertebra, Intervertebral disc, Lumbar vertebra and Coccyx  
 (c) Cervical vertebra, Intervertebral disc, Sacrum and Coccyx  
 (d) Lumbar vertebra, Intervertebral disc, Sacrum and Coccyx

20. Which of the following sarcomeres is labelled correctly [NCERT]



21. Osteoporosis, an age related disease of skeletal system, may occur due to [NEET (Phase-II) 2016]  
 (a) Accumulation of uric acid leading to inflammation of joints  
 (b) Immune disorder affecting neuromuscular junction leading to fatigue  
 (c) High concentration of  $\text{Ca}^{++}$  and  $\text{Na}^+$   
 (d) Decreased level of estrogen

## Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

- (a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion  
 (b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion  
 (c) If the assertion is true but the reason is false  
 (d) If both the assertion and reason are false  
 (e) If the assertion is false but reason is true

1. Assertion : Ball and socket joints are the most mobile joints.  
 Reason : Synovial fluid is present here.  
 2. Assertion : Locomotion in *Hydra* is carried out by two types of contractile cells.  
 Reason : Muscle fibres are lacking in *Hydra*.  
 3. Assertion : Triceps is said to be an extensor muscle for elbow joint.  
 Reason : Triceps relaxes during extension of forearm at the elbow joint.  
 4. Assertion : Muscle contraction force increases with rise in strength of stimulus.  
 Reason : This is due to increased contraction of individual muscle fibres with increase in stimulus strength

## Answers

### Axial skeleton

1	b	2	d	3	a	4	d	5	c
6	d	7	c	8	d	9	d	10	c
11	e	12	b	13	b	14	b	15	a
16	b	17	b	18	d	19	b	20	d
21	b	22	c	23	b	24	d	25	c
26	a	27	d	28	c	29	c	30	c
31	d	32	d	33	c	34	c	35	c
36	c	37	d	38	b	39	c	40	d
41	b	42	a	43	c	44	a	45	a
46	d	47	d	48	a	49	b	50	c
51	a	52	a	53	a				

### Appendicular skeleton

1	d	2	c	3	c	4	b	5	c
6	a	7	b	8	a	9	a	10	d
11	d	12	c	13	a	14	c	15	a
16	d	17	b	18	a	19	c	20	b
21	a	22	b	23	b	24	a	25	a
26	a	27	a	28	a	29	a	30	d
31	b	32	d	33	a	34	a	35	d
36	c	37	b	38	a	39	b	40	d
41	b	42	c	43	c	44	c	45	b

### Joints

1	a	2	c	3	d	4	b	5	c
6	a	7	d	8	d	9	a	10	b
11	b	12	a	13	d	14	b	15	d
16	a	17	b	18	d	19	a	20	a
21	c	22	a	23	a	24	b	25	c
26	d	27	c						

## Muscles

1	c	2	a	3	a	4	c	5	b
6	a	7	d	8	c	9	a	10	d
11	c	12	a	13	c	14	c	15	a
16	a	17	d	18	b	19	a	20	c
21	c	22	b	23	d	24	a	25	d
26	b	27	b	28	a	29	d	30	b
31	d	32	d						

## NCERT Exemplar Questions

1	c	2	b	3	b	4	c	5	d
6	a	7	b	8	c	9	d	10	c
11	b								

## Critical Thinking Questions

1	d	2	d	3	b	4	b	5	d
6	d	7	a	8	a	9	b	10	d
11	d	12	b	13	d	14	d	15	b
16	c	17	c	18	d	19	c	20	d
21	d								

## Assertion and Reason

1	b	2	a	3	c	4	c
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# AS

## Answers and Solutions

## Axial skeleton

4. (d) In the procoelous vertebrae, the anterior surface is concave and posterior surface convex.
14. (b) Since it has a single occipital condyle.
15. (a) The cranial cavity in which the brain is lodged posteriorly opens by foramen magnum. The brain is connected to spinal cord at this foramen.
16. (b) The eighth, ninth and tenth pairs of ribs are called false ribs. They articulate by cartilage with costal cartilage of the seventh rib.
20. (d) Vertebrae of birds are mostly heterocoelous.
21. (b) Cervical vertebrae are 7 in number, thoracic 12 in number, lumbar 5 in number, sacral 5 in number in childhood, they fuse in adults to form a single bone, the sacrum coccygeal vary from 3–5 in number.
23. (b) Long neck of camel is due to bony plates between two vertebra (which are long).
24. (d) *Sella turcica* or 'Turkish saddle' is a depression in the floor of the mammalian skull in the sphenoid (Basi sphenoid) bone in which the pituitary body is lodged.
26. (a) Immoveable/fixed/fibrous joint are present between the skull bones. So, between parietal bone and the temporal bone of the skull are joined by fibrous joint.

27. (d) The last two pairs (11th and 12th) of ribs which have no connection with the sternum at all are known as floating ribs.
29. (c) The first two or three lumbar vertebrae has another unpaired additional process, the hypapophysis, which extends downwards from the midventral part of centrum.
31. (d) Pterygoid is short rod shaped bone forming the posterior roof of mouth cavity.
32. (d) Thoracic vertebrae are 12 in number, present in the chest.
34. (c) Acoelous means without cavity on either of its ends. It can be amphiplatyon with both ends flats or amphidicondylar with both ends convex. Procoelous have anterior concavity, amphicoelous has both sides concave.
36. (c) The skull bones fit together by sutures.
37. (d) According to Greek mythology, their one God Atlas supports the earth. If the skull can be considered as the globe (earth), then first vertebra which bears whole of its weight can be regarded as Atlas. It is named on this basis only.
38. (b) Parasphenoid bone is a flattened and inverted T-shaped bone which lies in the median along the floor of cranium.
39. (c) 12 pair ribs are present in human beings, 1<sup>st</sup> to 7<sup>th</sup> pairs are called true ribs, 8<sup>th</sup>, 9<sup>th</sup>, 10<sup>th</sup> pairs are called false ribs, and last two pairs of ribs are called floating ribs.
41. (b) Number of bones in skull is 28
 

Bones of Cranium	= 8
Facial bones	= 14
Ear ossicles	= $\frac{6}{28}$
42. (a) The cranium is formed by 8 bones. (1 frontal bone, 2 parietal, 2 temporal, 1 occipital, 1 sphenoid, 1 ethmoid).
43. (c) The cranial segment is also cartilaginous in tadpole larva, but later, most of it changes into a tubular bone called sphenethmoid.
44. (a) It forms the main axis. It consists of skull – 22 bones, vertebral column – 33 vertebrae, sternum – 1 and ribs – 24.
46. (d) The dorsal, ventral and lateral part of thoracic basket are respectively formed of thoracic vertebrae, sternum, and ribs.
47. (d) Half of the vertebrate pelvic girdle consists of three bones ilium, ischium and pubis which fuse together in adult to be called innominate bone (hip bone).
48. (a) Hyoid bone is attached with the some muscles of the tongue and floor of the mouth.
50. (c) Cervical vertebrae are located in neck region.
53. (a) Human has 12 pairs of ribs, out of which first 7 pairs are called true or vertebrostermal ribs, next 3 pair are called false or vertebrochondral ribs and last 2 pairs are called floating or vertebral ribs.

## Appendicular skeleton

1. (d) In rabbit, radius and ulna are separate bones but they are joined at both ends by ligaments.
2. (c) Glenoid cavity articulates humerus with scapula.
3. (c) Patella is the small bone in knee joint between femur and tibia. It is a sesamoid bone developed in the tendon of quadriceps femoris muscle.

4. (b) The protein present in the bone is known as ossein. Which activate the bone formation.
5. (c) Each upper arm or brachium of mammals also has a single long humerus bone whose swollen, spherical, and smooth proximal end or "head" fits into a glenoid cavity of the pectoral girdle on its side.
8. (a) All mature cartilages are surrounded by a firmly attached, dense fibrous sheath of connective tissue, called perichondrium.
9. (a) The labelled parts are a – Clavicle, b – Scapula, c – Humerus and d – Ulna\* (Wrongly given as Radius).
11. (d) Humerus is the bone of upper arm. It articulates with ulna of fore arm. Two depression just above trochlea on anterior aspect are coronoid fossa and radial fossa respectively receives coronoid process of ulna and head of radius. One large depression on the posterior aspect is olecranon fossa receives olecranon process of ulna in extension of elbow.
12. (c) Synsacrum is the thoracic region of vertebral column in fowl. It consist of about 16 fused vertebrae and provide support to ilia bones of immense pelvic girdle.
13. (a) Synsacrum is a composite bone in birds which consists of about 16 fused vertebrae of different regions.
17. (b) Appendicular skeleton is situated at the lateral sides which actually extend outwards from the principal axis. It consists of pectoral and pelvic girdle and bones of arms and legs.
18. (a) A bone kept in KOH remain unaffected, only the surrounding muscles and connective tissue get dissolved, so that the bone now appears clean.
20. (b) Human skeleton is mainly formed of bones and cartilages. It is formed of 206 bones in adult man.
21. (a) Each hind limb contains 30 bones namely femur in thigh, patella in the knee, tibia and fibula in the lower leg, 7 tarsals in the ankle, 5 meta-tarsals in the sole and 14 phalanges in toes.
25. (a) Within the matrix of the compact bone of the shaft of long mammalian bones, (like humerus, femur, tibia), a network of branching canals (called haversian canals) is present in which lie the blood vessels.
27. (a) Ends of long bones are covered with cartilage. Ends of long bones takes part in forming the joint so the ends are covered by hyaline cartilage (articular cartilage).
28. (a) Ulna is produced into an olecranon process, to articulate into olecranon fossa and trochlea of humerus by a hinge joint.
29. (a) Each leg of cockroach is consist of five segments i.e., basal flat coxa, a small trochanter a long femur, a slender spiny tibia, and the foot tarsus.
31. (b) Astragalus and calcaneum are the bones of hind limb.
32. (d) Humerus is differentiated into three parts head, shaft and lower end. Shaft has a V-shaped deltoid ridge, at its middle
33. (a) Pelvic girdle comprises of the usual three bones ilium, ischium and pubis which are fused together into a single innominate or hip bone
35. (d) The ulna is thicker and longer, which bears a subterminal cup like receptacle called sigmoid notch or olecranon notch, for articulation with the distal end of humerus.
36. (c) The clavicle and interclavicle form a V-shaped furcula or wish bone or merrythought in birds.
38. (a) Ankle, also called tarsus, has 6 bones, called tarsals, arranged in three rows having gliding joints, proximal row is with two bones. Outer calcaneum (heel bone) and inner talus.
40. (d) The ventral part of each half of pectoral girdle is comprise three skeletal pieces scapula, supra scapula, and coracoid.
41. (b) Hip bone is formed by the fusion of three bones; ilium on upper side, pubis on inner side and ischium below the pubis.
42. (c) Haversian canals are present in long bones such as humerus, femur, tibia etc.
43. (c) 1 humerus, 1 radius, 1 ulna, 8 carpal bones, 5 metacarpal bones, 5 digits (14 phalanges) phalangeal formula 2,3,3,3,3.
44. (c) Ulna projects beyond the radius as an olecranon process which has a deep sub terminal sigmoid notch for articulation with the distal end of humerus.

### Joints

1. (a) An example of gliding joint is zygapophysis of adjacent vertebrae.
2. (c) Movable joints are called synovial joints. Which is found between humerus and ulna.
5. (c) The elbow joint.
8. (d) Shoulder and hip joints are the examples of ball and socket joints.
10. (b) Hyaline cartilage forms the articular surfaces at the joints of long bones where it is called as Articular cartilage.
14. (b) A gliding joint is the simplest of the synovial joints. Gliding joints are found between the carpal bones and between the tarsal bones.
17. (b) Hip joint (a type of ball and socket joint) found between head of femur and acetabulum of pelvic girdle.
18. (d) Achilles tendon is the strongest and thickest tendon in the body. Former is a large tendon at lower end of the gastrocnemius muscle, inserted into os calcis.
20. (a) Ligaments connects the two bones together and acts as a shock absorber to cushion when tibia and femur came together.
21. (c) Ligaments are the tissues which join the ends of bones together.
24. (b) Articular ends of both bones are either flat or slightly curved. To allow gliding or sliding movements as between zygapophysis of vertebrae.
25. (c) Tendon is a tough non-elastic connective tissue that joins a muscle to a bone. It is consists of collagen fibres.

### Muscles

1. (c) Sarcolemma is present on the outside of skeletal muscle fibre. In the region of attachment, the sarcolemma is folded to form finger like projections
2. (a) Fascia, actually is a sheet of connective tissue which covers the muscle
8. (c) It is the principal calf muscle in the leg of a tetrapod. It arises by two heads connected to condyles of the femur. At its lower end it has a strong tendon which joins with that of the soleus muscle to form the tendon Achilles. Its main action is to provide the propelling force for walking and running.



9. (a) Myosin protein forms anisotropic band and its centres forms 'M' line i.e. muscle fibre itself consists of myosin filaments. The cross bridges present in myosin molecules are enzymatic in nature and always tends towards, the centre of myosin filament thus causes the contraction of muscle fibre.
14. (c) During muscle fatigue due to deposition of lactic acid, cytoplasm becomes acidic thereby enzyme activity stops and food is not oxidised and as the energy is not available, muscular contraction stops.
16. (a) A-band has its middle a light zone called H-zone.
17. (d) There are about 639 types of muscles in human body which form about half of body weight.
18. (b) Myosin filaments are thicker and confined to the A-bands only. They are composed of myosin protein.
22. (b) In Cori's cycle large glycogen is broken down to lactic acid by glycolysis and energy is liberated. Some energy is used for regeneration of creatine phosphate and also for conversion of  $4/5^{\text{th}}$  of lactic acid back to glycogen. The remaining  $1/5^{\text{th}}$  of lactic acid is broken to  $\text{CO}_2$  and  $\text{H}_2\text{O}$ .
23. (d) During muscle contraction, myosin and actin form cross bridges. This complex is known as actomyosin complex.
24. (a) Biceps is flexor muscle, it is attached with humerus and radius bone through tendon. Biceps bends or flexes arm at elbow.
25. (d) Red muscles have large number of mitochondria which can utilize more stored oxygen thereby producing more ATP so are termed as aerobic muscles.
26. (b) They help in accommodation of lens.
29. (d) It helps in adduction, extension and medial rotation of the shoulder as in swimming, rowing, climbing, pulling, folding the arm behind back and scratching the opposite scapula. It also helps in violent expiratory efforts as coughing, sneezing, etc.
11. (d) In birds, the fore limbs are modified to form wings.
12. (b) Hinge joints are found in the knee, elbow, ankle and interphalangeal joints. Thus interphalangeal joints are also called hinge joints.
13. (d) The excess ATP is used to synthesize creatine phosphate, an energy rich molecule that is found in muscle fibres.
14. (d) The stapedius muscle, which is innervated by the facial nerve (cranial nerve VII), is the smallest of all skeletal muscles.

### Assertion and Reason

1. (b) Synovial fluid is a thick sticky fluid of egg white consistency, secreted by synovial membranes into the synovial cavity. Though the presence of synovial fluid is one of the reasons behind the mobility of the joints, but the most accurate reason is the arrangement of the bones at the joint, the spheroidal ball-like end of one bone articulates here with the cup-shaped depression in another. This allows the bone with the ball head to be moved freely in many planes. Shoulder joints and hip joints are the ball-and-socket joints.
2. (a) As muscle fibres are lacking in *Hydra*, the animal uses two types of contractile cells for this purpose. Processes of these cells run in the body wall both along the long axis of the body and around the central body cavity. Contraction and relaxation of these cells respectively, shorten and elongate these processes. They consequently cause all types of movement of *Hydra* including shortening, elongation and also bending of body and tentacular movement. Locomotion is carried out by somersaults looping.
3. (c) Movements are produced at joints by contraction of skeletal muscles inserted into articulating bones. The contraction of an extensor muscle extends a joint, hence causing extension of the limb. Contraction of triceps brings about the extension of forearm at the elbow joint hence it is said to be the extensor muscle for elbow joint.
4. (c) The muscle fibre always contracts with the maximum force and this force doesn't rise on increasing the strength of the stimulus. If the stimulus is of strength below the threshold, then the muscle fibre doesn't contract at all. This is known as All or None law. But the entire muscle doesn't obey this law, it means that force of contraction of muscle increase with rise in strength of the stimulus. This is due to the fact that the strength of the threshold stimulus varies from muscle fibre to muscle fibre in a muscle.

### Critical Thinking Questions

1. (d) In aquatic mammals (sirenia) cervical vertebrae are fused into a solid bony mass because of reduced neck in the manatees (sea cow) there are six cervical vertebrae only and the neural arches are sometimes incomplete.
5. (d) Squamosal is the posteriormost bone of the ramus. A zygomatic process extends forwards from its outer part.
7. (a) Epiphyseal plate (hyaline cartilage) is formed between diaphysis and epiphysis. This contributes in bone elongation.
8. (a) The greater trochanter and lesser trochanter are projections that serve as points of attachment for the tendons of some of the thigh and buttock muscles.
10. (d) Haversian canals are the characteristic features of bone.

## Locomotion and Movement

## SET Self Evaluation Test

1. The smooth sustained contraction of a muscle due to fusion of many twitches is called

(a) Tendon (b) Tetanus  
(c) Twitch (d) Rigor mortis

2. Bucket-handle movements is seen in [WB JEE 2010]

(a) 1<sup>st</sup> rib (b) 3<sup>rd</sup> rib to 5<sup>th</sup> rib  
(c) 6<sup>th</sup> rib to 10<sup>th</sup> rib (d) 11<sup>th</sup> and 12<sup>th</sup> rib

3. The characteristics and an example of a synovial joint in humans is [MP PMT 2011; NEET 2013]

	Characteristics	Examples
(a)	Lymph filled between two bones, limited movement	Gliding joint between carpals
(b)	Fluid cartilage between two bones, limited movements	Knee joint
(c)	Fluid filled between two joints, provides cushion	Skull bones
(d)	Fluid filled synovial cavity between two bones	Joint between atlas and axis

4. Pick out the correct match [AIIMS 2009]

(a) Sternum – 14 (b) Pelvis – 3  
(c) Ribs – 20 (d) Face – 5

5. The cranium is formed of 8 bones. They are

(a) 1 frontal, 2 parietals, 1 occipital, 2 temporals, 1 sphenoid and 1 ethmoid  
(b) 1 frontal, 1 parietal, 2 occipitals, 1 temporal, 2 sphenoids and 1 ethmoid  
(c) 2 frontals, 1 parietal, 1 occipital, 2 temporals, 1 sphenoid and 1 ethmoid  
(d) None of the above

6. The muscles associated with the heart of insects are

[Pb. PMT 1999]

(a) Alary (b) Radial  
(c) Striped (d) Pericardial

7. Which of the following bones are cartilaginous

[CPMT 1999; JIPMER 2001]

(a) Exoccipital and frontoparietal  
(b) Exoccipital and sphenoid  
(c) Exoccipital and parasphenoid  
(d) Frontoparietal only

8. Intercalated discs are found in [MP PMT 1993, 2000]

(a) Tendons (b) Striped muscles  
(c) Unstriped muscles (d) Cardiac muscles

9. Biceps and Triceps surround [CPMT 1999; MP PMT 2001]

(a) Radius (b) Ulna  
(c) Humerus (d) Femur

10. A cotyloid bone is found in

(a) Pelvic girdle of frog (b) Pelvic girdle of rabbit  
(c) Pectoral girdle of rabbit (d) Skull of frog

11. Fabellae bones are associated with [MP PMT 2002]

(a) Angular joint (b) Elbow joint  
(c) Knee joint (d) Neck joint

12. Which of the following structure joins biceps muscles with radius-ulna [CPMT 1995]

Or

Humerus and muscles are connected with [CPMT 1993]

(a) Tendon (b) Small muscles  
(c) Ligament (d) None of the above

13. Sometimes the muscles do not relax and become stiff. This condition is known as Rigor Mortis which is due to fall of concentration of

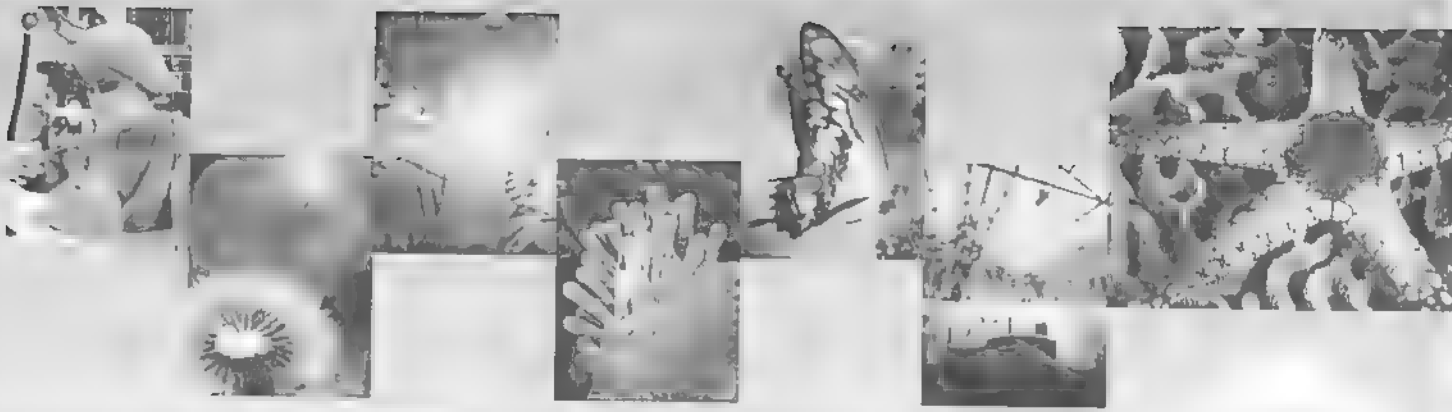
(a) Myosin (b) Relaxin  
(c) Actin (d) ATP

## Answers and Solutions

1	b	2	c	3	d	4	b	5	a
6	a	7	b	8	d	9	c	10	b
11	c	12	a	13	d				

12. (a) Tendon is very dense, strong fibrous connective tissue made of collagen fibres, which connects a skeletal muscle to a bone.

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## Neural Control and Coordination

In all the multicellular animals above the level of sponges, the system meant to perceive stimuli detected by the receptors, to transmit these to various body parts, and to effect responses through effectors, is called *nervous system*. In vertebrates, it is highly specialized and plays at least three vital roles

(1) **Sensory function** : It senses certain changes (stimuli) both within body (internal environment) and out side body (external environment).

(2) **Integrative functions** : It analyses the sensory information, store some aspects, and make decisions regarding appropriate behaviour.

(3) **Motor functions** : It may respond to stimuli by initiating muscular contractions or glandular secretions

### Nervous systems in various animals

(1) **Coelenterata** : True nerve cell or ganglion cells occur for the first time in coelenterates. They are derived from interstitial cells of epidermis, forming nerve net or nerve plexus below whole epidermis. A polar neurons are found in coelenterata.

(2) **Platyhelminthes** : Nervous system of planarians marks the beginning of a centralized nervous system encountered in higher animals. That is made up of brain or cerebral ganglia, two lateral longitudinal nerve chords, numerous peripheral nerves and transverse commissures or connectives. This is sometimes called the ladder type of nervous system.

In Nematoda (e.g. ascaris) these system made up of central nervous system, peripheral nervous system and rectal nervous system. Rectal nervous system more developed in male. Ascaris with dorsal, ventral, and lateral nerve cords.

(3) **Annelida** : Nervous system well developed and concentrated. It consists of three parts : central nervous system, peripheral nervous system and sympathetic nervous system, central N.S. made up of Nerve ring and ventral nerve cord. Nerves are of mixed type, consisting of both afferent (sensory) and efferent (motor) fibres.

(4) **Arthropoda** : The nervous system of prawn or arthropod is of the annelidan type. However it is somewhat larger and has more fusion of ganglia. It consists of (i) The central nervous system including brain connected with a ventral, ganglionated nerve cord through a pair of circum-oesophageal commissures, (ii) The peripheral nervous system including nerves and (iii) The sympathetic nervous system. In arthropods like cockroach sympathetic nervous system also known as stomatogastric nervous system, made up of 4 ganglion and retro-cerebral complex.

(5) **Mollusca** : In gastropodes (e.g. pila) consists of paired ganglia, commissures and connective uniting them and nerves running from these central organs to all parts of the body. It has various type of ganglia as cerebral, buccal, pleuro-pedal, supra intestinal and visceral etc. In polycypoda nervous system is greatly reduced due to sluggish and sedentary mode of life and there is little evidence of the brain. But in cephalopoda shows a high grade of organization attained only by some insects and arachnids among the other invertebrates.

(6) **Echinodermata** : Echinodermites has simple and primitive type of nervous system. It has the form of a nerve net, consisting of nerve fibres and a few ganglion cells, all confined to the body wall except the visceral nerve plexus situated in the gut wall. At certain places the nervous tissue is concentrated to form distinct nerve cords. It is made up of (i) Superficial or ectoneural nervous system (ii) Hyponeural or deep nervous system (iii) Aboral or coelomic nervous system and (iv) Visceral nervous system.

(7) **Hemichordata** : Nervous system is of primitive type resembling that of coelenterates and echinodermites, with both dorsal and ventral nerve cord

(8) **Chordates** : Nervous system well developed and formed by ectoderm. It is formed by central nervous system, peripheral nervous system and autonomic nervous system.

## Development of central nervous system in human

Nervous system begins developing early in third week of development from ectoderm. Nervous tissue also develop from ectoderm except microglial cell, develop from mesoderm. The central nervous system of vertebrates includes the brain and the spinal cord. These are derived from a longitudinal mid-dorsal ectodermal thickening of the embryo, called the medullary or neural plate. This neural plate or neural groove is converted by fusion into a closed mid-dorsal longitudinal neural tube lying above the notochord. Histologically, the embryonic neural tube exhibits three zones of cells.

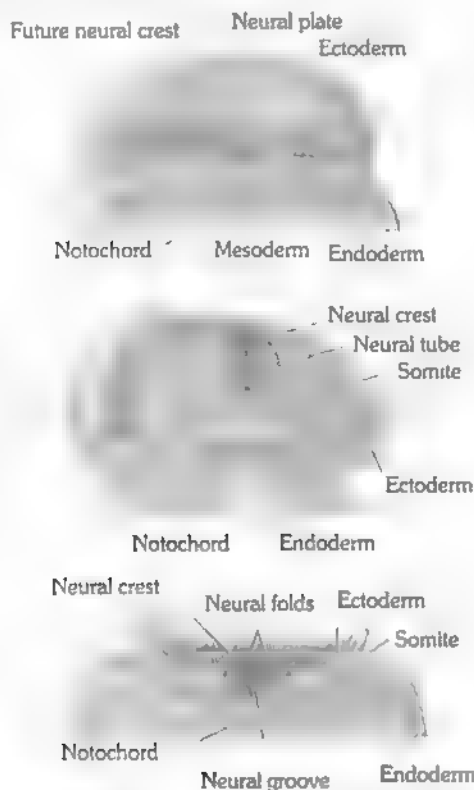


Fig : 5.6-1 Stages in the embryonic development of central nervous system

(1) **Germinal layer** : These are actively dividing cells lining the neural canal. They form the connective tissue lining of neural canal, called *ependyma*, and ventricles of brain.

(2) **Mantle layer** : It consists of embryonic neurons or *nematoblasts*, forming the grey matter.

(3) **Marginal layer** : It consists of nerve fibres, mostly surrounded by fatty myelin sheaths, and forms the *white matter*. Neurons and fibres are supported by a special connective tissue of ectodermal origin, the *neuroglia*, cells of which become increasingly abundant and diversified in higher vertebrates.

### Development of brain

The anterior end of embryonic neural tube is already enlarged forming the embryonic brain, called *encephalon*. By differential growth and two constrictions, it is divided into a linear series of three *primary cerebral vesicles*, termed the *forebrain*, *midbrain* and *hindbrain*. These give rise to the three major divisions of the adult

brain – (1) *prosencephalon* (forebrain), (2) *mesencephalon* (midbrain), and (3) *rhombencephalon* (hindbrain). These further become subdivided into 5 subdivisions. Prosencephalon divides into an anterior *telencephalon* and posterior *diencephalon*; the mesencephalon remain unchanged. The rhombencephalon divides into an anterior *metencephalon* and a posterior *myelencephalon*. Ultimately, telencephalon develops into cerebral hemisphere and basal ganglia and houses lateral ventricle. Diencephalon develops into thalamus, hypothalamus, and pineal gland and houses the third ventricle. Mesencephalon develops into mid brain and houses cerebral aqueduct. Metencephalon develops into pons and cerebellum; and myelencephalon develops into medulla oblongata, houses 4<sup>th</sup> ventricle. The area of neural tube inferior to myelencephalon gives rise to spinal cord.

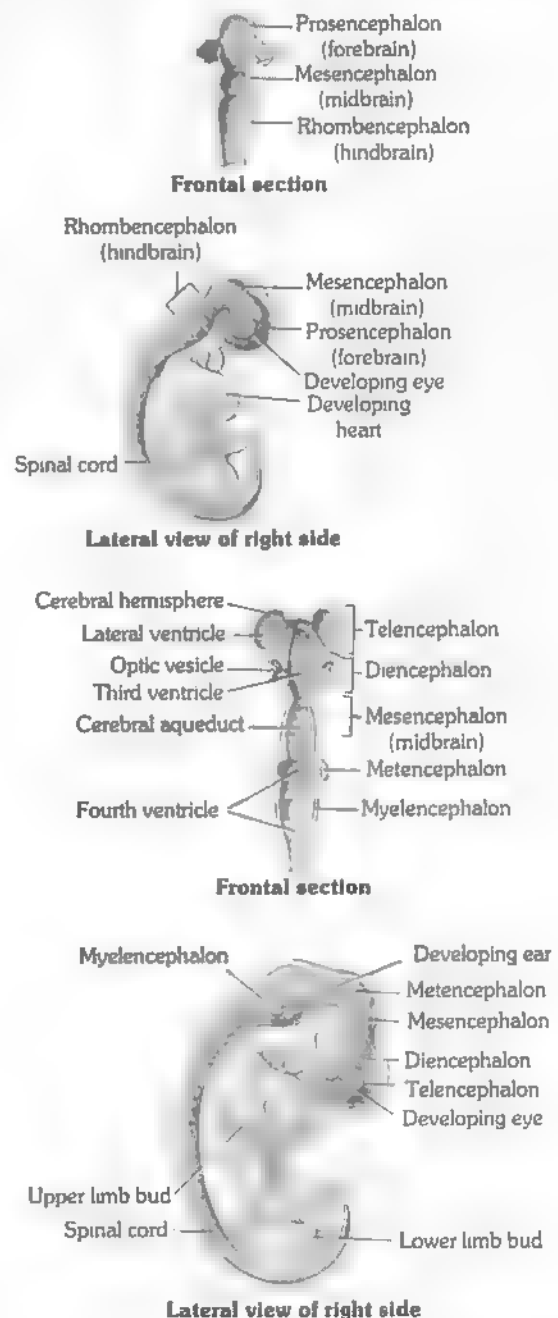
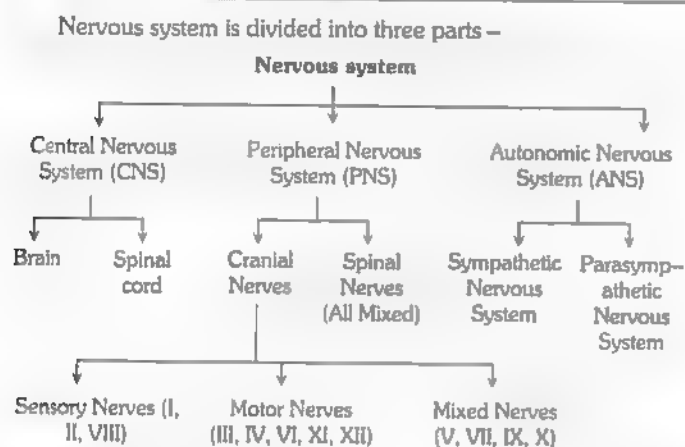


Fig : 5.6-2 Development of the brain and spinal cord

## Parts of nervous system



### Central nervous system (CNS)

In all the vertebrates including man, CNS is dorsal, hollow and non-ganglionated while in invertebrates when present, it is ventral, solid, double and ganglionated. CNS is formed of two parts :

(1) **Brain** – Upper and broader part lying in the head.

(2) **Spinal cord** – Lower, long and narrow part running from beginning of neck to trunk. CNS is covered by 3 meninges and its wall has two type of matter.

**Types of matter** : CNS of vertebrates is formed of two types of matter –

(i) **Grey matter** : It is formed of cell-bodies, non-medullated nerve fibres, neuroglia, dendrites of association neurons and motor neurons.

(ii) **White matter** : It is formed of medullated nerve fibres or myelinated axon of motor and sensory neurons, which appear white due to the presence of medullary sheath.

**Meninges** : The meninges are connective tissue membranes which surround the brain and spinal cord of CNS. In the fishes, there is only one meninx called meninx primitiva (pia mater). In amphibians, reptiles and birds, the brain is covered by two meninges or membranes : inner pia-arachnoid and outer duramater. In mammals, CNS is covered by three meninges or membranes or cranial meninges. Brain meninges are continuous with spinal meninges

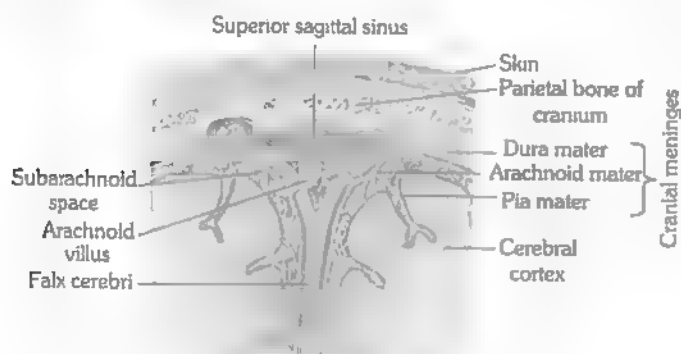


Fig : 5.6-3 Meninges of brain

The three layers of cranial meninges in order from superficial to deeper duramater, arachnoid and pia mater. Duramater is nonvascular, tough made up of fibrous connective tissue. Arachnoid mater made up of reticular connective tissue with collagen and elastin fibre, while innermost vascular pia mater (nutritive) made up of loose areolar connective tissue. Between dura and arachnoid mater presence of sub dural space (no CSF in mammals here), between Arachnoid and pia mater presence of sub-arachnoid space (with CSF in mammals, CSF also found in ventricles and central canal). Between duramater and periosteum presence of epidural space. An extension of duramater between two cerebral hemispheres is called falx cerebri. Tentorium, an extension of duramater between cerebrum and cerebellum.

**Cerebrospinal fluid** : All the ventricles of the brain, central canal of spinal cord are continuous and lined by a columnar, ciliated epithelium, the ependyma. They contain lymph-like extracellular fluid called the cerebrospinal fluid (C.S.F.). This fluid is secreted by the choroid plexuses by filtration of blood. The choroid plexuses consist of loose connective tissue of pia mater covered internally by a simple cuboidal epithelium of secretory (glandular) nature. The cerebrospinal fluid slowly flows toward the fourth ventricle by secretion pressure and passes into the spinal cord. Some fluid escapes into the subarachnoid spaces through three pores a median aperture (of magendie) and a paired lateral aperture (of Luschka) in the roof of the fourth ventricle in the medulla. From the subarachnoid spaces, the cerebrospinal fluid is transferred to the blood of the venous sinuses. Nervous tissue is without lymphatic vessels.

The cerebro-spinal fluid (CSF) provides –

- (i) Protection to brain from mechanical shocks, physical injury.
- (ii) Optimum physiological fluid environment for neural functions e.g. conduction of nerve impulses, transport of aminoacids, sugars,  $O_2$  etc.
- (iii) 'Relief' mechanism for the increase in intracranial pressure that occurs with each arterial pulse of blood to brain.
- (iv) 'Sink' like facility for metabolites of brain
- (v) The blood CSF barrier for selective transport process between blood and CSF.
- (vi) Nourishment to CNS.

Major site of CSF formation is choroid plexus, and mid ventricular wall and sub-arachnoid wall also contribute. CSF is cell free, slightly alkaline, and is isotonic to plasma. Rate of formation of C.S.F is 20 ml/h (480 ml/day) approx, 1/2 litre per day. Total amount present in and around CNS is 80-150 ml it means there is atleast 3 times renewal of C.S.F. every day. CSF contains glucose, proteins, lactic acid, urea,  $Na^+$ ,  $K^+$ ,  $Ca^{2+}$ ,  $Mg^{2+}$ ,  $Cl^-$ ,  $HCO_3^-$  and some WBC

Blood brain barrier facilitate maintenance of stable internal environment. It acts as physiological and pathological barrier.

❑ **Hydrocephalus** : The enlargement of head, a pathological condition characterized by an abnormal accumulation of cerebrospinal fluid resulting in headache, vomiting, pain and stiffness of the neck.

- ❑ Increased cerebrospinal fluid may result in Meningitis.
- ❑ Meningitis may occur due to infection and inflammation of meninges or injury of meninges.
- ❑ Infection may be viral, bacterial or both. The most common cause of meningitis is the infection of *Streptococcus pneumoniae*, *Neisseria meningitidis* and *Haemophilus influenzae*.
- ❑ Lumbar puncture is done for drainage of excess of cerebrospinal fluid during meningitis.
- ❑ Cerebro-spinal fluid is formed by choroid plexus (ACP and PCP).

There are three choroid plexus in humans –

- (i) **Lateral choroid plexus** : It is in the roof of I and II ventricle.
- (ii) **Anterior choroid plexus** : It is in the roof of III ventricle (diocoel).
- (iii) **Posterior choroid plexus or pelochoroida** : It is in the roof of IV ventricle

**Oxygen and glucose requirements** : Brain controls the functions of our body organs and also provides the qualities of mind – learning, reasoning, and memory. For these activities, brain needs a large and constant energy supply. At any given time, the activities of the brain account for 20% of the body's consumption of oxygen and 15% of its consumption of blood glucose. Brain deprived of oxygen for just 5 minutes is permanently damaged. Mental confusion results if brain is deprived of glucose.

#### Structure of human brain (Encephalon)

It is soft, whitish, large sized and slightly flattened structure present inside cranial cavity of cranium of the skull. In man, it is about 1200-1400 gm in weight and has about 10,000 million neurons. Brain is made up of 3 parts :

- (1) **Fore brain or Prosencephalon** : It forms anterior two-third of brain and is formed of three parts.

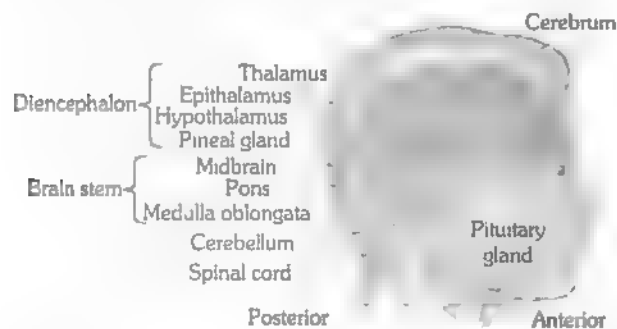


Fig : 5.6-4 Main parts of human brain visible from lateral view

**Olfactory lobes** : These are one pair, small sized, club-shaped, solid, completely covered by cerebral hemisphere dorsally. Each is differentiated into two parts –

- (i) **Olfactory bulb** : Anterior, swollen part, and
- (ii) **Olfactory tract** : Posterior and narrow part which ends in olfactory area of temporal lobe of cerebral hemisphere.

**Function** : These control the smell.

- (a) It is normal in frog, rabbit and man.
- (b) It is well developed in dog. So power of smell is more in dog.

- (c) These are also well developed in dog fish and name dog fish is on the basis of well developed olfactory lobes

**Cerebrum** : Cerebrum is divided into 5 lobes (a) frontal (b) parietal, (c) occipital, (d) temporal and (e) Insula. A lobe called insula is hidden as it lies deep in the sylvian fissure. The cerebral hemisphere are separated from olfactory lobes by rhinal fissure. The median fissure divides the cerebrum into a right and a left cerebral hemisphere.

A few sulci are well developed and form three deep and wide fissures which divide each cerebral hemisphere into four lobes – anterior frontal lobe, middle parietal lobe, posterior occipital lobe and lateral temporal lobe e.g. Fissure sulcus lying between the frontal and parietal lobes is central fissure or sulcus, that is lying between the parietal and occipital lobes is parieto-occipital fissure and that demarcating frontal and parietal lobes from the temporal lobe is lateral or Sylvian fissure. Each cerebral hemisphere is with a fluid-filled cavity called lateral ventricle or paracoel.

Two cerebral hemispheres are interconnected by thick band of transverse nerve fibres of white matter called corpus callosum. The peripheral portion of each cerebral hemisphere is formed of grey matter and is called cerebral cortex, while deeper part is formed of white matter and is called cerebral medulla. Cerebral cortex is the highest centre for many sensations and activities and is with a number of sensory areas. Cerebral cortex 2-4 mm thick.

**Histology of cerebrum** : The whole brain possess grey matter outside and white matter inside around ventricle.

- (i) **Grey matter** : In cerebrum grey matter is very much developed, it is on an average 2-4 mm. thick but at poles its thickness is 1.3 mm. It is thickest at pre central gyrus (4.5 mm thick). Grey matter of cerebrum is called cortex or pallium. Phylogenetically or evolutionarily cortex is divided into 3 parts –

(a) **Allocortex or paleocortex** : It is the cortex of olfactory area of frontal lobe and olfactory bulbs. In lower vertebrates (cartilaginous fish) olfactory lobes occupy most of the part of cerebrum. So in these animals sense of olfaction is very-very much developed. Sense of olfaction is oldest sense.

(b) **Mesocortex** : It is relatively not much older in development.

(c) **Neocortex or neopallium or Isocortex or neencephalon** : It is most recent cortex and is developed maximum only in human. It is in prefrontal cortex or prefrontal region (organ of mind), precentral and postcentral gyrus etc. The neocortex is having 6 layer of neurons while remaining cortex possess only 5 layers.

The cerebral cortex is having area of about 2200 cm<sup>2</sup> while the cranial cavity is only 1450 cm<sup>3</sup>, so to accommodate cerebrum there appears foldings in the cortex. The ridges are called gyrus (or gyri) or convolution while the depression are called sulcus (sulci in plural).

- (ii) **White matter** : It is inner part of brain. White matter is aggregation of myelinated and unmyelinated axons of many neurons. Its fibres are divided into 3 categories .

(a) **Commissural fibres** : These neurons connect gyri of 2 hemispheres, such as corpus callosum, habenular commissure, anterior commissure, posterior commissure.

(b) **Associate fibres** : They connect gyri of same hemisphere.

(c) **Projection neuron** : They are infact ascending and descending nerve tract, they connect one part of brain to another part of brain or to spinal cord. (In spinal cord they were called as column).

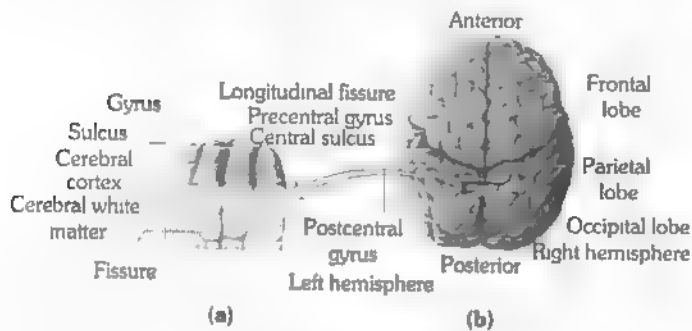


Fig : 5.6-5 (a) Details of gyrus, sulcus and fissure, (b) Posterior superior view of cerebrum

**Associated structures of cerebrum** : Cerebrum has following specific structure.

(i) **Sub cortex** : Nuclei on white matter. It is cluster of grey neurons in depth of white matter, they are formed in whole brain and are named differently.

(ii) **Basal ganglia or central nucleus** : These are several groups of nuclei in each cerebral hemisphere.

**Corpus striatum** : Corpus striatum is the largest nucleus, consist of caudate nucleus and lenticular nucleus. The lenticular nucleus is sub-divided in putamen (outer shell) and globus pallidus (ball). Other structure, functionally linked to and some times considered part of basal ganglia are

(a) **Clastrum** : It is the name given to grey matter present between insula and putamen.

(b) **Epistriatum or Amygdaloid body** : It is structure present at the end of caudate nucleus.

(c) **Red nucleus and substantia nigra** of mid brain.

(d) **Sub thalamic nuclei of diencephalon.**



Fig : 5.6-6 Basal ganglia

### Function of basal ganglia

(i) **Caudate and putamen** control large automatic movements of skeletal muscle like swinging of arm while walking.

(ii) **Globus pallidus** control muscle tone for specific body movements.

(iii) **Corpus callosum** : It is the band of white neurons present between both cerebral hemisphere and connect them on medial surface. It is present only in mammal. It has anterior part genu, middle part trunchus and last part splenium.

Below corpus callosum there are two fused band of white neurons called fornix. There anterior part is called column and posterior part is called crura. Between column and genu a membrane is called septum lucidum or septum pellucidum. Septum lucidum encloses a space called  $V_s$  or Pseudocoel, because it is not possessing C.S.F. i.e. why it is called pseudocoel.

(iv) **Limbic system** : Limbic system present on inner border of cerebrum and floor of diencephalon. It is also called emotional brain or animal brain. Limbic system controls emotion, animal behaviour like chewing, licking, sniffing, docility, tameness, affection (animals) rage, pain, pleasure, anger, sexual feelings, fear, sorrow grooming. It has following structure –

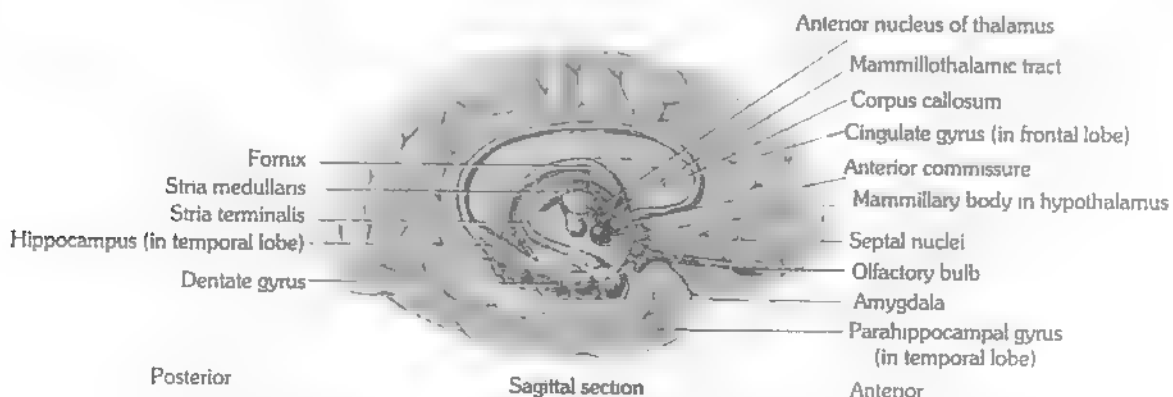


Fig : 5.6-7 Components of limbic system and surrounding structure

- (a) **Cingulate gyrus** : It is a region of pre central gyrus
- (b) **Hippocampal gyrus** : It is a region of temporal lobe near collosomarginal sulcus. These two structure are combinely called limbic lobe.
- (c) **Amygdaloid body** : It is the end of caudate nucleus.
- (d) **Olfactory bulb** : They are on the inferior anterior surface of brain. Olfactory nerve ends in these bulb.
- (e) **Mammillary body** : They are found in hypothalamus. Olfactory bulb and mammillary body both are centre of olfaction
- (f) **Dentate gyrus** : Is in between hippocampus and parahippocampale.
- (g) Anterior nucleus of thalamus is located in floor of lateral ventricle.

**Diencephalon** : Diencephalon cavity is called, III ventricle or diocoel the thin roof of this cavity is known as the epithalamus, the thick right and left sides as the thalami, and floor as the hypothalamus.

(i) **Epithalamus** : It forms the roof of third ventricle. The epithalamus is not formed of nervous tissue. It consists of piamater only. Hence, it is of relatively little significance as a nerve centre. Its anterior part is vascular and folded. It is called anterior choroid plexus. Behind this plexus, the epithalamus gives out a short stalk, the pineal stalk which bears a small, rounded body, the pineal body, at its tip, and paired right and left habenular nuclei (olfaction or smell).

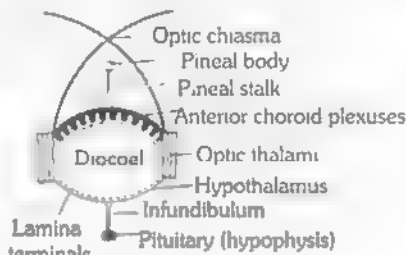


Fig : 5.6-8 Diencephalon

(ii) **Thalamus** : A pair of mass of grey matter forms the superior part of lateral walls of the third ventricle. It measures 3 cm in length and comprises 80% of diencephalon. The thalamus is principal relay station for sensory impulses that reach the cerebral cortex from spinal cord, brain stem, cerebellum. It also allows crude appreciation of some sensations such as pain, temperature, and pressure. Certain nuclei in the thalamus relay all sensory input to cerebral cortex. These include the –

- (a) Medial geniculate nucleus for hearing.
- (b) Lateral geniculate nucleus for vision.
- (c) Ventral posterior nucleus for taste, touch, pressure, vibration, heat, cold, and pain.

Other nuclei are centres for synapse in somatic motor system their include.

(a) Ventral lateral nucleus and ventral anterior nucleus (voluntary motor actions).

(b) Anterior nucleus concerns with emotions and memory.

(iii) **Hypothalamus** : The hypothalamus is visible in the ventral view of the brain and forms the floor of diencephalon. Hypothalamus also gives a nervous process called infundibulum (forms pars nervosa) which meets a rounded non-nervous pharyngeal outgrowth called hypophysis. Both collectively form master gland called pituitary body. A stalked outgrowth of infundibulum combines with a pouch-like epithelial outgrowth (Rathke's pouch) of the roof of embryonic mouth (= stomadeum), forming a pituitary gland or hypophysis. Which secretes a number of hormones. In front of hypothalamus, there is crossing of two optic nerves called optic chiasma. Behind the hypothalamus, there is one pair of small, rounded, nipple-like bodies called mammillary bodies or corpora mammillares. The hypothalamus consists of many masses of grey matter, called hypothalamic nuclei, scattered in the white matter.

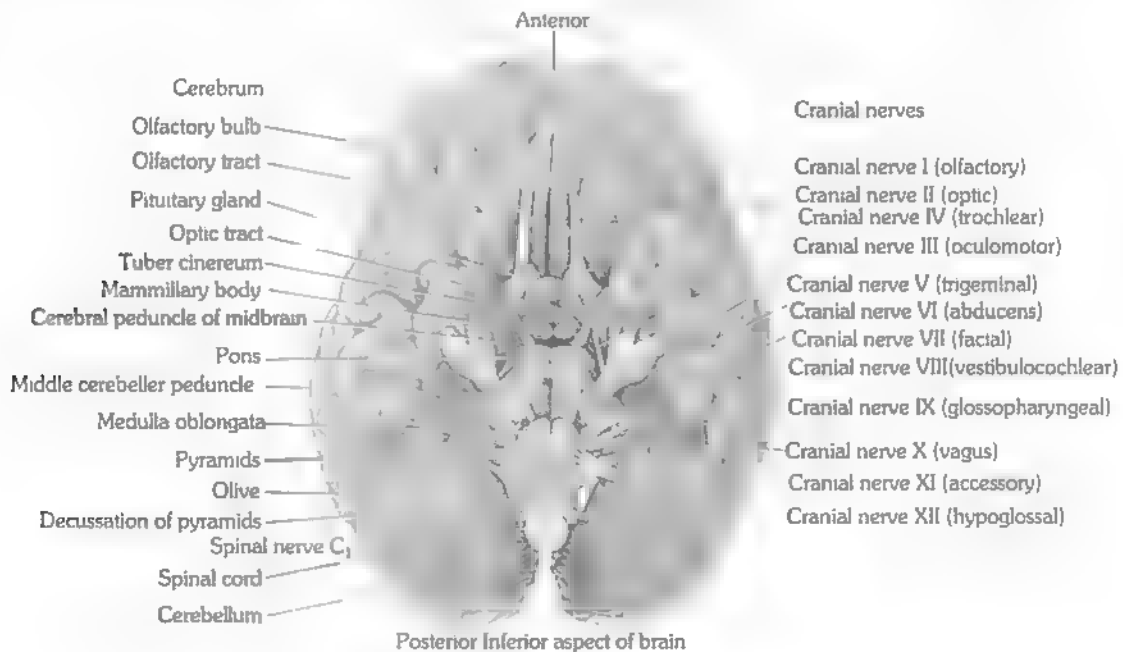


Fig : 5.6-9 Ventral view of brain



In man and some other mammals, most fibres of optic nerves cross, but some fibres do not cross and innervate the eyes of their own respective sides. This arrangement enables man and these mammals to have a binocular vision. Rabbits simply have a monocular vision.

Pineal gland is a pine cone-shaped gland. It is located in the centre of brain with which it loses all nervous connection after birth. It is innervated by sympathetic nerves. It has a photosensory role in amphibian and primitive reptiles and is called 'Third eye'. Pinealocytes secrete melatonin. Mammalian pineal does not act as photoreceptor but it produces the hormone called melatonin which is anti FSH, and anti LH. It inhibits reproductive function. Melatonin secretions decrease after puberty.

### Functions of fore brain

(i) **Olfactory lobe** : It is centre of smell.

(ii) **Cerebrum** : Cerebral cortex is made up of grey matter and differentiated into –

(a) **Sensory and associated area** confirm, recognise and evaluate for shape, colour, sound, taste and smell for sensory cells in relation with object.

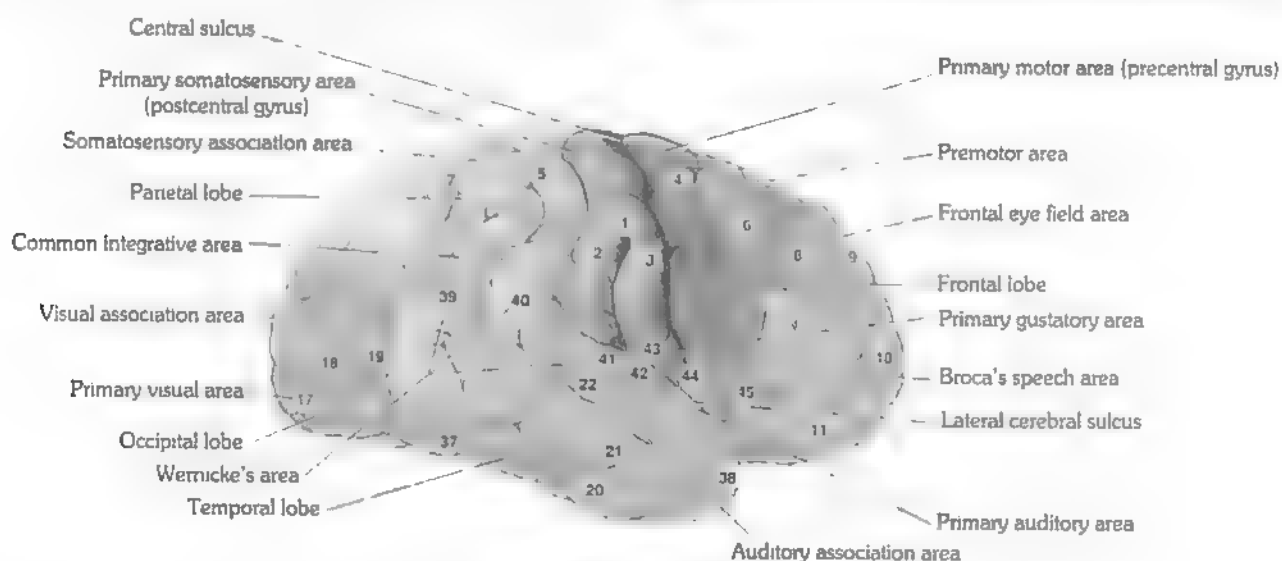
b) **Broca's area** : Known as sensory speech area or motor speech area. Translate thought into speech. Located into frontal lobe towards left side. It is associated with language area and also

interpret translation of written words into speech. Damage or injury in Broca's area (sensory or motor speech area) may result.

Aphasia(Inability to speak), Word deafness, Word blindness.

**Table : 5.6-1 Important areas in the human brain**

Area	Location	Function
Premotor area	Frontal lobe	The highest centre for involuntary movements of muscles and ANS
Motor area	Frontal lobe	Controls voluntary movements of the specific muscle
Broca's area	Frontal lobe	Motor speech area (Translation of thought and written words into speech)
Somesthetic area	Parietal lobe	Perception of general sensation like pain, touch and temperature
Auditory area	Temporal lobe	Hearing (Interprets characteristics of sound such as pitch and rhythm.
Olfactory area	Temporal lobe	Sense of smell
Wernicke's area	Temporal lobe	Understanding speech, written and spoken
Gustatory area	Parietal lobe	Sense of taste
Visual area	Occipital lobe	Sensation of light



**Fig : 5.6-10 Functional areas of the cerebrum**

(c) **Cerebrum is a centre for** – Intelligence, Emotion, Will power, Memory, Consciousness, Imagination, Experience, Knowledge, Reasoning, Voluntary controls, Weeping and laughing, Micturition, Defecation.

☐ If cerebrum is removed animal becomes simple reflex animal.

(iii) **Diencephalon is a centre for** :

(a) Carbohydrate metabolism

(b) Fat metabolism

(c) It relays impulses from posterior region of brain and also to posterior region of brain.

- (d) It secretes neurohormone
- (e) Form part of pituitary gland
- (f) Secrete cerebrospinal fluid

(iv) **Hypothalamus is a centre for** – Hunger, Thirst, Sweating, Sleep, Fatigue, Temperature, Anger, Pleasure, love and hate, Satisfaction.

- ☐ It is also centre to release factors for endocrine glands.
- ☐ It also control A.N.S (autonomic nervous system)
- ☐ Centres for regulation of parasympathetic (cranio-sacral) activity. When stimulated, it causes slowing down of heart beat, contraction of the visceral muscles.

(2) **Mid brain or mesencephalon** : Extends from pons to diencephalon, contain both white and grey matter. Posterior portion of mid brain is called tectum. It is also completely covered by cerebral hemisphere. It is formed of two parts –

(i) **Optic lobes** : These are one pair, large sized lobes present on dorsal side. Each is divided transversely into upper and larger superior colliculus and lower and smaller inferior colliculus. So there are four optic lobes, so called optic quadrigemina (only in mammals). In frog these are known as bigemina. **Valve of Vieussens**. It joins the optic lobe with cerebellum.

(a) **Superior optic lobe or superior colliculus** : They are concerned with reflex action of eye, head and neck in response to visual stimulus.

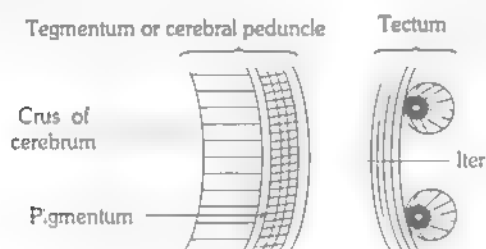


Fig : 5.6-11 Lateral view

(b) **Inferior colliculus** : They are concerned with movement of head and trunk in response to hearing stimulus.

(ii) **Cerebral peduncle (crura cerebri)** : They are the pair of thick bands of longitudinal nerve fiber present on the floor or ventral side of mid brain. The dorsal part of cerebral peduncle (white matter) is called Tegmentum while most ventral part (grey matter) is called crura cerebrae or crus of cerebrum. Dorsal thick wall of mid brain is known as optic tectum. Iler is between tegmentum and tectum. Cerebral peduncle are in fact possessing ascending and descending tracts, connecting upper and lower region of brain.

In white matter of cerebral peduncle these are following sub cortical structure

(a) **Red nucleus or rustrum nucleus** : They are red because of rich blood supply and iron containing pigment or haemoglobin. Function with basal ganglia and cerebellum to coordinate muscular movement.

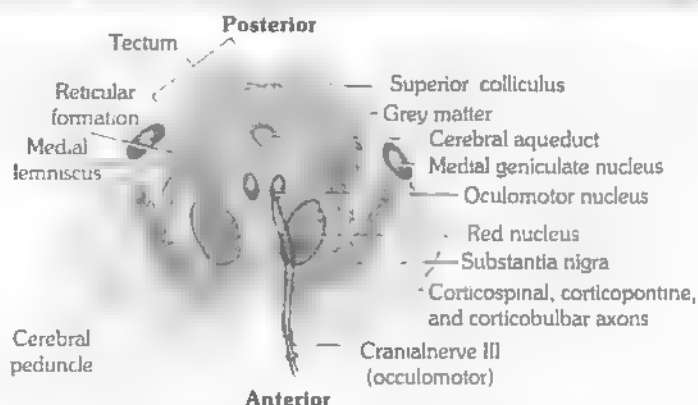


Fig : 5.6-12 T.S. of midbrain

(b) **Substantia nigra** : It is black because of much deposition of melanin.

(c) **Oculomotor nucleus** : It is origin point of 3rd cranial nerve (oculomotor) from this region 4th (Trochlear) nerve also originates.

#### Functions of Mid brain

(i) Pair of anterior optic lobes (which are also known as superior colliculi) is related with vision.

(ii) Pair of posterior optic lobe (known as inferior colliculi) related with auditory function.

(iii) These act as coordination centres between hind and fore brain.

(3) **Hind brain** : Hind brain consists of (i) cerebellum and (ii) medulla oblongata (iii) Pons varolii.

(i) **Cerebellum (Sandwiched brain)** : Cerebellum is second largest portion of brain which lies posterior to medulla and pons and inferior to posterior portion of cerebrum. Cerebellum is separated by cerebrum by a transverse fissure and by an extension of cranial dura mater called tentorium cerebelli. Cerebellum is butterfly shape consist of :

- (a) The central constricted area is vermis
- (b) A lateral wings or lobes called cerebellar hemispheres with anterior and posterior lobe (govern skeletal muscle movement).
- (c) The flocculo nodular lobe (sense of equilibrium).

Between cerebellar hemisphere is extension of cranial dura mater called falx cerebelli. The superficial layer of cerebellum, called cerebellar cortex, consist of grey matter in series of parallel ridges called folia. Deep to grey matter is white matter tree called 'Arbor vitae' or tree of life. Cerebellum is attached to brain stem by three paired cerebellar peduncles –

- (a) Inferior cerebellar peduncle between cerebellum and medulla with sensory/motor fibre.
- (b) Middle cerebellar peduncle between cerebellum and pons with sensory axon
- (c) Superior cerebellar peduncle between cerebellum and mid brain, mainly with major fibre.

Cerebellum receives sensory impulses from proprioceptors in muscle, joint, and tendons, coordinate skeletal muscle contractions and also regulate posture and balance.

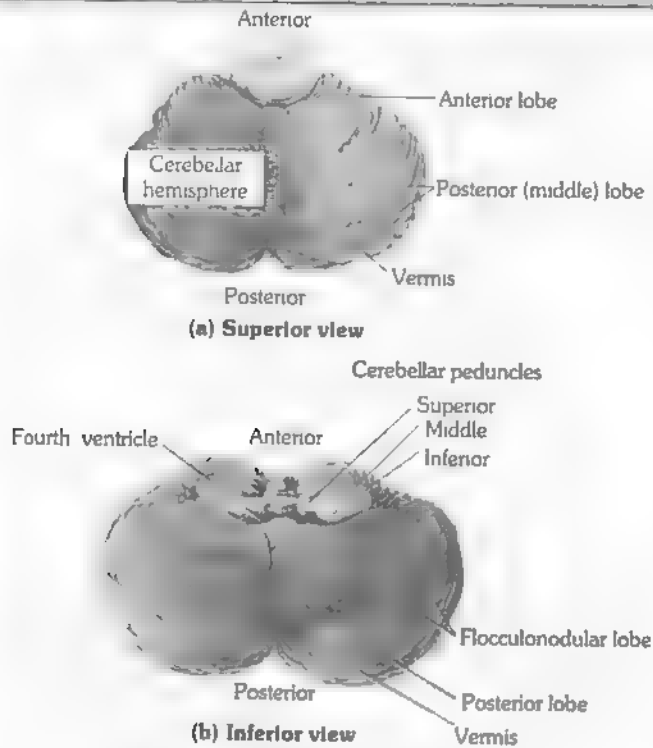


Fig : 5.6-13 Structure of Cerebellum

### (ii) Medulla oblongata

Medulla oblongata is the hindmost and posterior most part of brain. Cavity is known as IVth ventricle (metacoel) which is continuous with central canal of spinal cord. It has a pair of lateral Foramina of Luschka and a median foramen magnum. Cerebrospinal fluid comes in contact by these apertures from internal cavity of the brain to outer fluid of meninges. An arrangement on its ventral surface there are bulgings of ascending and descending tract which are called pyramids. On the ventral surface these pyramids cross each other which is called decussation of pyramids. On the dorsal side of medulla there are two nuclei which are called nucleus gracilis (long) and nucleus cuneatus. On floor of  $V_4$  there is a groove called calamus scriptorius.

In the medulla oblongata, most of the sensory and motor fibres cross from one side to the other. Thus, the left cerebral hemisphere controls the right side of the body and vice versa. The reason for this is not known. The lower end of medulla passes into the spinal cord. There is no demarcation between the two. However, the medulla is considered to start at the level of the foramen magnum of the cranium. Medulla contains nuclei of origin of 5 pairs of cranial nerves, VIII, IX, X, XI and XII. VIII – vestibulocochlear nerve is concerned with hearing and equilibrium. (There are also nuclei for vestibular branch of VIII in pons).

(i) **Pons Varolii** : An oval mass, of white matter called the pons varolii, lies above the medulla oblongata. It consists mainly of nerve fibres which interconnect as a bridge connecting spinal cord with brain and parts of brain with each other. Pons also has a pneumotaxic area and apneustic area. Together with medullary rhythmicity area, they help in controlling respiration.

### Functions of hind brain

#### Cerebellum –

- (i) Poorly developed in frog but well developed in mammal.

- (ii) It is centre for co-ordination of muscular movement.

- (iii) It is primary centre for balancing, equilibrium, orientation.

#### Medulla oblongata contains centre for –

- (i) Heart beats
- (ii) Respiration
- (iii) Digestion
- (iv) Blood pressure
- (v) Gut peristalsis
- (vi) Swallowing of food
- (vii) Secretion of gland
- (viii) Involuntary function – e.g. vomiting, coughing, vasoconstrictor, vasodilator, sneezing, hiccupping.
- (ix) It controls urination, defecation.
- (x) The cardiovascular centre – regulate rate, force of heart beats.
- (xi) Medullary rhythmicity area – adjust basic rhythm of respiration.

#### Cavities or ventricles of the brain

The ventricles consist of four hollow fluid-filled spaces inside the brain and same duct for connection between these ventricles.

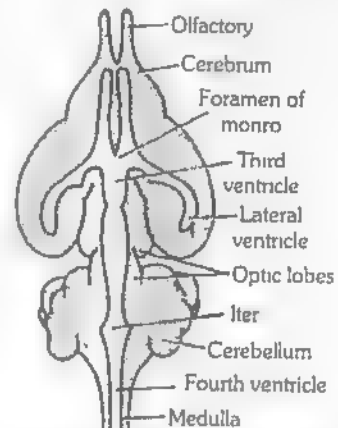


Fig : 5.6-14 Ventricles of brain of rabbit

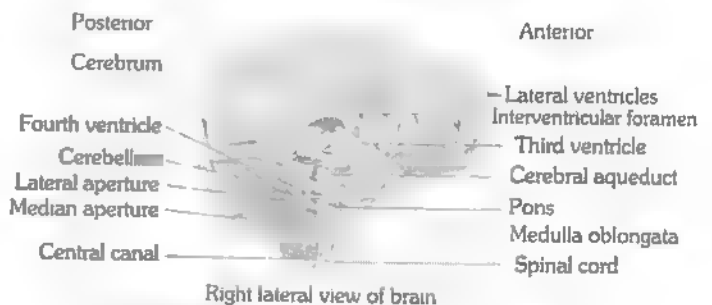


Fig : 5.6-15 Diagram showing ventricles of human brain

- (1) Olfactory lobe – Rhinocoel
- (2) Cerebrum – I and II ventricle or lateral ventricle or paracoel.
- (3) Foramen of Monro : I and II ventricle communicating with IIIrd ventricle by foramen of Monro. They are two in human and single in rabbit and frog
- (4) Diencephalon : Third ventricle or Diocoel.

(5) **Iter or cerebral aquiduct or aquiduct of sylvius** : It is very narrow cavity between III and IV ventricle.

(6) **Optic lobe** : Optocoel

(7) **Cerebellum** : Solid

(8) **Medulla oblongata** : 4th ventricle or metacoel.

Cavities of brain and spinal cord are modified neurocoel. They are lined by low columnar ciliated epithelium called **ependyma**.

**Table : 5.6-2 Subdivisions, parts and associated structures of a vertebrate brain**

Divisions	Subdivisions	Parts	Cavity	Associated structures
(I) Prosencephalon (Forebrain)	(1) Telencephalon	Rhinencephalon	I Ventricle (Rhino-coel)	Olfactory bulbs, Olfactory tracts, Olfactory lobes, Palaeocortex on pallium
		Cerebral hemispheres	II or Lateral Ventricles (Paracoels) ↓ Foramen of Monro	Corpora striata or basal ganglia, Corpus callosum, Neocortex on pallium, Paraphysis
	(2) Diencephalon	Epithalamus (roof)	↓ III Ventricle (Diocoel)	Habenulae, Pineal apparatus, Parapineal or parietal
		Thalamus (sides) superior		
		Hypothalamus (floor), Inferior side		Hypothalamic nuclei, Optic chiasma, Median eminence, Infundibular stalk, Pituitary, Saccus vasculosus, Mamillary bodies, Anterior choroid plexus
(II) Mesencephalon (Midbrain)	—	Crura cerebri (floor)	Iter or cerebral aqueduct	Corpora quadrigemina (superior colliculi, inferior colliculi), Tectum, substantia nigra and red nuclei.
(III) Rhombencephalon (Hind brain)	(1) Metencephalon	Cerebellum		Trapezoid body, Pons
	(2) Myelencephalon	Medulla oblongata	IV Ventricle (Metacoel)	Resolom bodies, Pyramids

**Salient or mammalian features of human brain** : The salient or mammalian features in the human brain are –

- (1) Relatively small, solid olfactory lobes.
- (2) Very large cerebral hemispheres divided into lobes and with highly folded surface, with cerebral cortex of grey matter.
- (3) Corpus callosum Interconnecting the cerebral hemispheres only found in eutheria.
- (4) Very small pineal body.
- (5) A pair of mamillary bodies joined to hypothalamus.
- (6) Relatively small, solid optic lobes divided into 4 corpora quadrigemina.
- (7) Large, solid cerebellum, with highly folded surface and divided into lobes.
- (8) Pons varolii present anterior to the cerebellum.

### Spinal cord

Present in spinal canal or vertebral canal of vertebral column. It is extended from foramen magnum to 12 lumbar vertebra. In new born infants, extend to 3 or 4 lumbar vertebra. Spinal cord is swollen in cervical and lumbar region which are called cervical and lumbar enlargement. The length of spinal cord ranges from 42 to 45 cm. Its diameter is about 2cm.

#### Structure of spinal cord

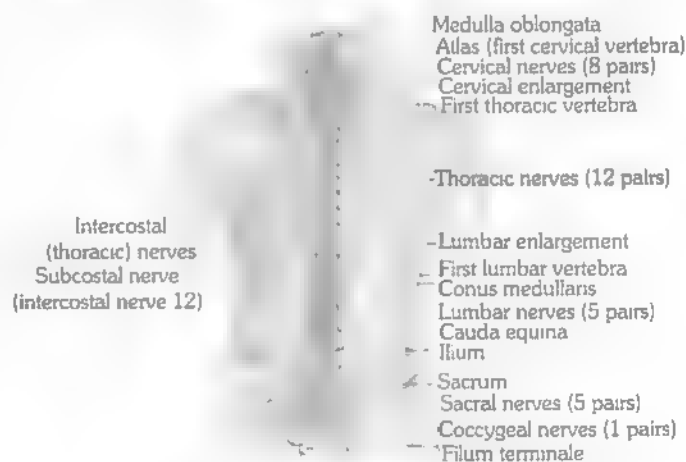
(1) **Conus medullaris** : It is last tapering end of spinal cord, its ciliated central canal is called Vth ventricle.

(2) **Cauda equina** : A horse tail-like collection of roots of spinal nerves at inferior end of the spinal cord. Some spinal nerves arise from inferior part of cord do not leave vertebral column at same level as they exit from spinal cord. The roots of these nerves angle inferiorly in vertebral canal from end of spinal cord like wisps of hair.

(3) **Filum terminale** : It is extension of pia mater below conus medullaris upto coccyx. In frog spinal cord also extends upto end of vertebral column.

(4) **Cisterna terminalis** : It is last dilation of subarachnoid space below 1st lumbar vertebra. It is a proper site for lumbar puncture or spinal tap, which is done to drain C.S.F out (5 to 10 ml). This C.S.F is used in diagnosing many diseases of CNS like meningitis, encephalitis, inter cranial pressure, meningococcal infection etc.

(5) **Meninges** : Like brain, spinal cord is also enclosed within three membranes. In this case duramater does not remain attached with the vertebra, instead there is a space between duramater and vertebra called epidural space. The epidural space is filled with a fluid. The distribution of duramater and pia mater in spinal cord is the same as that of brain.



**Fig : 5.6-16 External anatomy of the spinal cord and the spinal nerves**

The cross section of spinal cord reveals the following structures –

(1) **Central canal** : In the centre of spinal cord, there is a canal called central canal. It is filled with cerebrospinal fluid. central canal is continuous with 4<sup>th</sup> ventricle of medulla oblongata.

(2) **Dorsal fissure** : In the mid dorsal line, there is a groove extending throughout its length.

(3) **Ventral fissure** : It is also a groove situated in the mid ventral line throughout the length of spinal cord.

(4) **Dorsal septum** : It is a partition extending from dorsal fissure to central canal.

(5) **Grey matter** : It lies around the central canal in the form of a butterfly and sub-divided into 3 horns, surrounded by white matter.

(6) **Dorsal horns** : It is like horn of grey matter on the dorsal side.

(7) **Ventral horns** : On the ventral side of the grey matter are horn like structures the ventral horns.

(8) **Lateral horns** : These are horns on the lateral side of grey matter.

(9) **White matter** : White matter is present around grey matter. Dorsal and ventral horn, divide white matter into 3 broad area on each side –

- (i) Anterior (ventral) white columns
- (ii) Posterior (dorsal) white columns
- (iii) Lateral white columns.

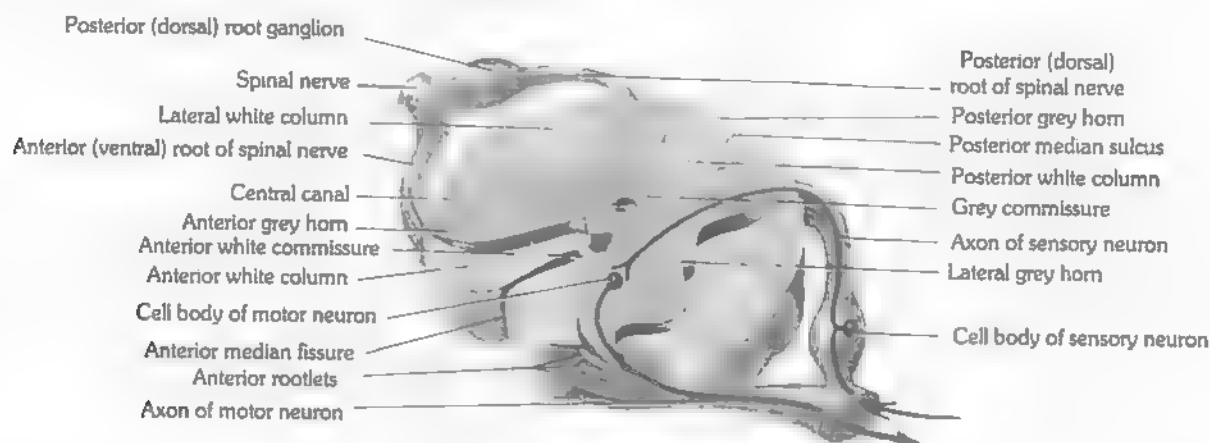


Fig : 5.6-17 T.S. of the thoracic spinal cord of mammal

**Reflex action** : Reflexes are fast predictable, automatic responses to change the environment. First of all Marshal Hall (1833) studied the reflex action. Best and Taylor defined reflex action "simplest form of irritability associated with the nervous system is reflex actions or a reflex reaction is an immediate involuntary response to a stimulus." The reflex actions are involuntary actions because these are not under the conscious control of the brain. Central nervous system is responsible for the control of reflex action.

Reflex arc is formed by the neurons forming the pathway taken by the nerve impulses in reflex action. The simplest reflexes are found in animals involving a single neuron and the following pathway –

Stimulus → Receptor → Neuron → Effector → Response

(1) **Component of reflex action** : The whole of the reflex includes five parts –

(i) **Receptor organs** : Receptors are windows of the body or guards of the body. These are situated on all, important organs, for example – eyes, nose, ear, tongue, integument etc. These perceive the stimuli from outside the body.

(ii) **Sensory neurons** : These are also termed afferent neurons. These carry the stimuli from receptors to spinal cord. These neurons are situated in the ganglion on the dorsal side of spinal cord grey matter or brain stem.

(iii) **Association neurons or Integrating centre** : These are also called intermediate neurons or interstitial neurons. These are found in spinal cord. They transfer the impulses from sensory neurons to motor neurons. Association neurons forms monosynaptic and polysynaptic reflex arc.

(iv) **Motor neurons** : These are situated in the ventral horn of spinal cord. These carry the impulses to effector organs.

(v) **Effector organs** : These are the organs, which react and behave in response to various stimuli, for example – muscles and glands.

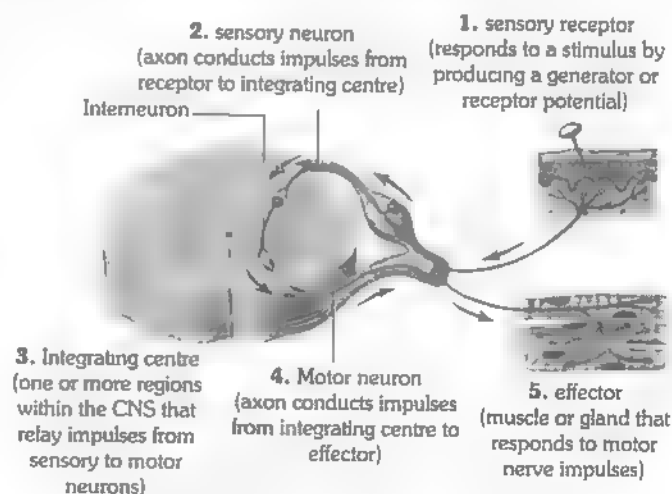


Fig : 5.6-18 General components of a Reflex arc

(2) **Mechanism of reflex action** : The time taken by a reflex action is too short, for example – in frog it is 0.3 metre per second and in man 5-120 metre per second. Whenever, a part of the body is stimulated by any stimulus, for example – pin pricking, then the stimulus is converted into impulse. This impulse is perceived by the dendrites of sensory neurons. From here, the stimulus reaches the spinal cord through axonic fibres. In the spinal cord, this stimulus passes through synaptic junctions and reaches the intermediate neurons, from where this stimulus reaches the effector organs through motor nerve fibres. As soon as the stimulus reaches the effector organs, it is stimulated and that part of the body is immediately withdrawn. The whole reflex action takes place so rapidly and quickly that we know it when it is completed.

(3) **Type of reflexes** : The reflexes are of following types –

(i) **Monosynaptic reflex** : This is the simplest reflex found in vertebrates. The sensory neuron synapses directly on to the motor neuron cell body. In this case the reflex action takes place without the involvement of brain.

(ii) **Polysynaptic spinal reflex** : This has at least two synapses situated within the spinal cord. It involves a third type of neuron also – the internuncial or inter-mediate relay neuron. The synapses take place between the sensory neuron and intermediate neuron, and between intermediate neuron and the motor neuron. These two reflex arcs allow the body to make automatic, involuntary, homeostatic adjustments, to changes in the external environment, such as the Iris pupil reflex and balance during locomotion, and also in the internal environment such as breathing rate and blood pressure.

(iii) **Polysynaptic spinal/brain reflexes** : In this case the sensory neuron synapses in the spinal cord with a second sensory neuron, which passes to the brain. The latter sensory neurons are part of the ascending nerve fibre tract and have their origin in preintermediate neuron synapse. The brain is capable of identifying this sensory information and stores it for further use. The motor activity may be initiated by the brain anytime and the impulses are transmitted down the motor neurons in descending nerve fibre tract, to synapse directly with spinal motor neurons in the postintermediate synaptic region.

(iv) **Simple reflex** : Simple reflex is also known as unconditioned reflex. It is inborn, unlearned, reflex to a stimulus. Simple reflex is mostly protective in function. Example of simple reflex are

(a) **Knee jerk** – Tendon of patella tapped, also called patellar reflex

(b) **Corneal reflex** (blinking reflex) – closing of eyelids.

(c) Rapid withdrawal of hand while burned or pricked.

(d) Quick recovery of balance while falling.

(e) **Scratch reflex** of frog – In pithed frog with acetic acid.

(f) Coughing, sneezing and yawning.

(v) **Acquired reflex** : Acquired reflex is also known as conditioned reflex. It is not inborn, but acquired and dependent on past experience, training and learning. Demonstration of conditioned reflex was first made by Russian physiologist Ivan Petrovitch Pavlov (1846-1936) in hungry dog. Pavlov rang the bell while feeding dog, thus associated the unconditioned response with additional stimulus. Examples of conditioned reflex are

learning of dancing, cycling, swimming, singing, driving, etc. These actions are under cerebral control during learning.

### Peripheral nervous system

It is formed of a number of long, thin, whitish threads called nerves extending between central nervous system and body tissues. Each nerve is formed of bundles of nerve fibres, fasciculi, held together by connective tissue and surrounded by a white fibrous connective tissue sheath called epineurium

The nerve fibres are classified into two categories on the basis of presence or absence of myelin (white fatty) sheath.

(1) Medullated or Myelinated nerve fibres.

(2) Non-medullated nerve fibres.

On the basis of function, the nerves are of three types

(1) **Sensory nerve**

(i) It contains only sensory nerve fibres.

(ii) It conducts nerve impulses from sense organs to CNS to produce sensation. e.g. Optic nerve, auditory nerve.

(2) **Motor nerve**

(i) It contains only motor nerve fibres.

(ii) It conducts nerve impulses from CNS to some muscles or glands to control their activities. e.g. Oculomotor nerve, hypoglossal nerve.

(3) **Mixed nerve**

(i) It contains both sensory and motor nerve fibres.

(ii) It conducts both sensory and motor impulses. e.g. All spinal nerves, trigeminal nerve.

On the basis of their origin, nerves are of two types

(1) Cranial or cerebral nerves which either arise from or end into brain.

(2) Spinal nerves which arise from spinal cord.

### Cranial nerves

(1) 10 pairs of cranial nerves are present in an anamniote (fishes and amphibians).

(2) Number of cranial nerves found in frog is ten pairs (20).

(3) 12 pairs of cranial nerves are present in an amniote (reptiles, birds and mammals).

(4) Number of cranial nerves found in rabbit and man is 12 pairs (24).

(5) The first 10 pairs are common for frog and rabbit. The additional pairs found in rabbit are spinal accessory and hypoglossal.

(6) The smallest cranial nerve is trochlear in human beings, but in all animals smallest cranial nerve is abducens.

(7) The largest cranial nerve is trigeminal in human beings but vagus is largest cranial nerve in all animals

(8) Vagus supplies the regions other than head.

(9) The sensory cranial nerves are

I Olfactory – Smell

II Optic – Vision

VIII Auditory – Hearing and equilibrium

(10) The motor cranial nerves are : III, IV, VI, XI and XII

(11) Extraocular muscle nerves are III, IV and VI.

(12) The mixed cranial nerves are : V, VII, IX and X (4 pairs)

(13) Number of cranial nerves in snake (Amniota) 10 pairs.

Table : 5.6-3 Cranial nerves of mammal at a glance

	Name	Nature	Origin	Distribution	Function
[I]	Olfactory Nerves	Sensory	Olfactory lobe	Sensory epithelium of olfactory sacs	Receive stimuli from the sensory epithelium of olfactory sac and carry them to olfactory lobes
[II]	Optic nerves	Sensory	In retina of eye	Lateral geniculate nuclei of thalamus	Stimulus of light is carried to optic occipital lobe of cerebral cortex.
[III]	Oculomotor nerves	Motor	Crura cerebri (mid brain)	Eye ball muscles like superior rectus, medial rectus, inferior rectus and inferior oblique. except superior oblique muscle and external rectus	Movement of eye lids and eye ball
[IV]	Trochlear nerves	Motor	From in between the optic lobes and cerebellum	Superior oblique muscle of eye ball	Movement of eye ball
[V]	Trigeminal nerves	Mixed	From the gasserian ganglia situated on the lateral side of pons	—	—
	(i) Ophthalmic nerve	Sensory	—	Skin of lips, upper eye lid, lacrimal gland	—
	(ii) Maxillary	Sensory	—	Upper lip, skin of nose, lower eye lid, Upper teeth.	Carry the stimuli from these organs to brain
	(iii) Mandibular nerve	Mixed	—	Lower lip and skin of jaw	Carry the stimuli from these organs to brain
[VI]	Abducens nerves	Motor	Pons	Eye muscles external rectus	Movement of eye ball
[VII]	Facial nerves	Mixed	Pons	—	—
	(i) Palatimus	Sensory	—	In the roof of mouth cavity	Carry the impulses from roof of mouth cavity
	(ii) Hyomandibular	Motor	—	Muscles of lower jaw, muscles of neck and pinna (external ear)	Carry the impulses from brain muscles of lower jaws, neck and pinna.
	(iii) Chordatympani	Mixed	—	In salivary glands and taste buds	Receives the stimuli from the taste buds and carry the stimulus to salivary gland.
[VIII]	Auditory nerves	Sensory	Medulla, pons	—	—
	(i) Vestibular nerve	—	—	Semicircular canals, saccule, utricle	Receives impulses from the internal ear and carry to brain for equilibrium
	(ii) Cochlear nerve	—	—	Cochlea	Impulses associate with hearing.
[IX]	Glossopharyngeal nerve	Mixed	In medulla	Taste buds present in tongue and muscles of oesophagus	Secretion of saliva, taste muscle sense (proprioception)
[X]	Vagus nerve	Mixed	Arising from medulla, 9 <sup>th</sup> and 10 <sup>th</sup> cranial nerves unite to form vagus nerve but become separate and divide into branches	—	—
	(i) Superior laryngeal nerve	Motor	—	Glottis, trachea, lung muscle	(1) Smooth muscles contraction and relaxation.
	(ii) Recurrent laryngeal nerve	Motor	—	Glottis, trachea, lung muscle	(2) Secretion of digestive juice. (3) Muscle sense (proprioception) (4) Sensation of visceral organs.
	(iii) Cardiac nerve	Motor	—	Heart Muscles	From brain to heart muscles
	(iv) Pneumogastric	Motor	—	In the abdominal cavity in stomach and lungs.	Carry impulse from these organs to brain and from brain to muscles of these organs.
	(v) Depressor nerve	Motor	—	Diaphragm	Carry the impulse to diaphragm
[XI]	Spinal accessory	Motor	Medulla	Muscles of neck and shoulders, voluntary muscles of pharynx, larynx, and soft palate	Swallowing movements, movement of head.
[XII]	Hypoglossal nerve	Motor	Medulla	Muscles of tongue and neck	Movement of tongue during speech and swallowing, proprioception (Muscle sense)

**Spinal nerves :** Spinal nerves arise from grey matter of spinal cord. There are 31 pairs of spinal nerves in man (37 pairs in rabbit). All spinal nerves are mixed. The spinal nerves in man are divided into 5 groups.

- (1) Cervical (C) → 8 pairs — in Neck region
- (2) Thoracic (T) → 12 pairs — in thoracic region
- (3) Lumbar (L) → 05 pairs — upper part of abdomen
- (4) Sacral (S) → 05 pairs — lower part of abdomen
- (5) Coccygeal (CO) → 01 pairs — represent the tail nerves
- Total = 31 pairs

Number of spinal nerves in frog is 10 pairs. In some frog like *Rana tigrina*, 10th pair may be reduced or absent. The first pair of spinal nerves in frog is hypoglossal. The last pair of cranial nerves of mammals has the same name. Brachial plexus is formed by 2nd and 3rd spinal nerves in frog. Sciatic plexus is formed by 7, 8 and 9 spinal nerves in frog. Glands of Swammerdam are calcareous glands found at the places of emerging of spinal nerves in frog.

Spinal nerve formula can be written as –  $C_8, T_{12}, L_5, S_5, CO_1$ . Spinal nerves exit via intervertebral foramen. Each spinal nerve arises from spinal cord by 2 roots

(1) **Dorsal (= Afferent = Sensory = Posterior) root** is a continuation of dorsal horn and is formed of grey matter. It presents a ganglionic swelling in middle, called dorsal root ganglion. These transmit sensory nerve impulses from the sense organs to spinal cord (touch, pain, temperature). They activate involuntary reflexes.

(2) **Ventral (= Efferent = Motor) root** are continuation of ventral horn and is also formed of grey matter. No ganglion are present. It is formed of only efferent nerve fibers. They transmit motor nerve impulses to effector organs e.g., glands and muscles. Each spinal nerve has 4 branches –

(i) **Ramus dorsalis :** Supplies to skin and muscles of dorsal side.

(ii) **Ramus ventralis :** Supplies to skin and muscles of ventral and lateral sides and also to upper and lower limbs. Ventral root of certain spinal nerve form 5 nerve plexi on either side, i.e., cervical, thoracic, lumbar, sacral, caudal.

(iii) **Ramus communicans :** It joins sympathetic ganglion of autonomic nervous system.

(iv) **Meningeal branch :** Vertebra, vertebral blood vessel.

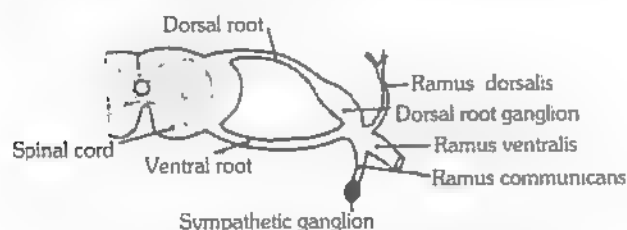


Fig : 5.6–19 Origin and distribution of spinal nerve

### Autonomic nervous system

Autonomic nervous system was discovered by Langley. Autonomic nervous system (ANS) automatically regulates the activities of smooth muscles, cardiac muscles and glands. This co-ordination is involuntary. Autonomic nervous system usually operates without conscious control. Autonomic nervous system is entirely motor. All autonomic axons are efferent fibres. Autonomic nervous system is regulated by centres in brain like cerebral cortex, hypothalamus and medulla oblongata. Autonomic fibres release chemical transmitters at synapse. On the basis of the transmitter produced, these fibres may be classified as cholinergic or adrenergic. Cholinergic fibres release acetylcholine. Adrenergic fibres produce norepinephrine (noradrenaline), also called sympathetin.

**Nature of autonomic control :** The autonomic nervous system regulates and co-ordinates such vital involuntary activities like heart beat, breathing, maintenance of the composition of body fluids (= homeostasis) and body temperature, gut peristalsis, secretion of glands, etc. Autonomic nervous system consists of two divisions –

#### (1) Sympathetic ANS (Thoracolumbar out flow)

- (i) Thoraco Lumbar out flow (all thoracic + 3 lumbar)
- (ii) Preganglionic nerve small.
- (iii) Post ganglionic nerve long.
- (iv) Preganglionic nerve secrete acetyl choline.
- (v) Postganglionic nerve secrete **sympathetin**. (nor-epinephrine)
- (vi) It shows sympathy (generally increase the function).
- (vii) Expenditure of energy takes place.
- (viii) It increase defence system of body against adverse condition.
- (ix) It is active in stress condition, pain, fear and anger.

#### (2) Parasympathetic ANS (Cranio-sacral out flow)

- (i) ANS Cranio sacral outflow (cranial-III, VII, IX, X Nerves)- (sacral-II, III, IV Nerves)
- (ii) Preganglionic nerve long.
- (iii) Postganglionic nerve small.
- (iv) Secrete acetyl choline only.
- (v) It provide relaxation, comfort, pleasure, at the time of rest.
- (vi) Restoration and conservation of energy takes place.
- (vii) Collateral ganglia present in sympathetic nervous system.
- (viii) **Horner's syndrome** results from the damage of sympathetic trunk of one side.
- (ix) A patient of Horner's syndrome exhibits lack of sweating (on affected side), sunken eyes and constricted pupil.



**Table : 5.6-4 Difference between sympathetic and Parasympathetic**

S.No.	Name	Sympathetic	Parasympathetic
1.	Secretion	Acetyl choline and Sympathetin	Acetyl choline only
2.	Blood pressure	Increase	Decrease
3.	Blood vessel to skin	Constrict	Dilate
4.	Blood vessel to heart	Dilate	Constrict
5.	Blood vessel to lung and muscle	Dilate	Constrict
6.	Pupil	Dilate	Constrict
7.	Lacrimal gland	Stimulate	Inhibits
8.	Heart beat	Increase	Decrease
9.	Adrenal secretion	Stimulate	Inhibit
10.	Breathing and BMR	Increase	Decrease
11.	Nostrils	Dilate	Constrict
12.	Urinary bladder	Relax	Constrict
13.	Iris	Constrict	Dilate
14.	Salivary gland	Decrease	Increase
15.	Digestive gland	Decrease	Increase
16.	Gut peristalsis	Decrease	Increase
17.	Ejaculation	Increase	Decrease
18.	Bile	Decrease	Increase
19.	Renin (kidney)	Increase	Decrease
20.	Bronchi	Dilate	Constrict

Cutting of sympathetic or parasympathetic nerve to heart will not stop functioning of heart. Heart will beat but without any nervous control. Autonomic nervous system functions rapidly to alter visceral functions (3-5 seconds). It is activated mainly by centres located in spinal cord, brain stem and hypothalamus. Limbic cortex also influences its function often this system function via visceral reflexes i.e. sensory signal → enter autonomic ganglia → spinal cord → brain stem → or hypothalamus can elicit reflex responses back to visceral organs to control their activities.

### Biochemical Aspect of Nervous Physiology

Nerve cells (= neurons) : Irritability is a basic characteristic of the "living substance", i.e., the protoplasm. Consequently, every living cell becomes excited when stimulated. However, the nerve cells and muscle fibres are specialized excitable cells of body, capable of transmitting or conducting excitations along their membranes. Of these, muscle cells are further specialized for contraction while nerve cells are further specialized for receiving stimuli (as sensory or receptor cells) and transferring excitations from one to the other.

A typical neuron consists of a nucleated cell body (= cyton, soma or perikaryon), five to seven short, slender and branched (= arborized) dendrites, and a single, relatively thicker and longer fibrous axon. The latter is terminally branched into short telodendria. Each telodendron bears a terminal **knob** or **button**. Buttons of one neuron lie upon dendrites or cytons of adjacent neurons (figure), or upon muscle fibres or glands.

**Nerve fibres** : Although, all parts of a neuron transmit excitations (= impulses), but the transmission is always unidirectional. The dendrites and cytons usually constitute the impulse receiving parts which receive impulses directly from receptors, or from other adjacent neurons. The axons are specialized as fibres conducting impulses away from the receiving parts. Thus, the reaction or response impulses are always carried to the effectors by axons. That is why, the term 'nerve fibres' is usually applied to the axons. The latter are 0.1 mm to one or more (upto 10) metres long and about 0.025 m thick on an average.

**Main properties of nervous tissue** : The nervous tissue has two outstanding properties excitability and conductivity

(1) **Excitability** : It is the ability of the nerve cells and fibres to enter into an active state called the **state of excitation** in response to a stimulus. Excitation arises at the receptors on account of various stimuli such as light, temperature, chemical, electrical or pressure which constantly act on the organisms.

(2) **Conductivity** : The excitation does not remain at the site of its origin. It is transmitted along nerve fibres. The transmission of excitation in a particular direction is called conductivity

**Definition of nerve impulse** : A wave of reversed polarity or depolarization (action potential) moving down an axon is called a nerve impulse.

### Mechanism of conduction of nerve impulse

Most accepted mechanism of nerve impulse conduction is ionic theory proposed by Hodgkin and Huxley. This theory states that nerve impulse is an electro-chemical even governed by differential permeability of neurilemma to  $\text{Na}^+$  and  $\text{K}^+$  which in turn is regulated by the electric field.

(1) **Transmission of nerve impulse along the nerve fibre**

(i) **Polarization (Resting membrane potential-RMP)** : In a resting nerve fibre (a nerve fibre that is not conducting an impulse), sodium ions ( $\text{Na}^+$ ) predominate in the extracellular fluid, whereas potassium ions ( $\text{K}^+$ ) predominate in the intracellular fluid (within the fibre). Intracellular fluid also contains large number of negatively charged (anions) protein molecules.  $\text{Na}^+$  are 10 times more outside the neuron and  $\text{K}^+$  ions are 25 times more inside the cell. Thus it makes a considerable difference between the ion concentration outside and inside the plasma membrane. It also causes a difference in electrical charges on either side of the membrane. The plasma membrane is electrically positive outside and negative inside. This difference is called potential difference. The potential difference across the plasma membrane is known as resting potential. This potential averages - 70 mv (- 40 to - 90 mv) in inner side of membrane in respect to outer side.

A higher concentration of cations outside the membrane compared to the concentration of cations inside it. This state of the resting membrane is called polarised state and makes its inner side electronegative to its outside

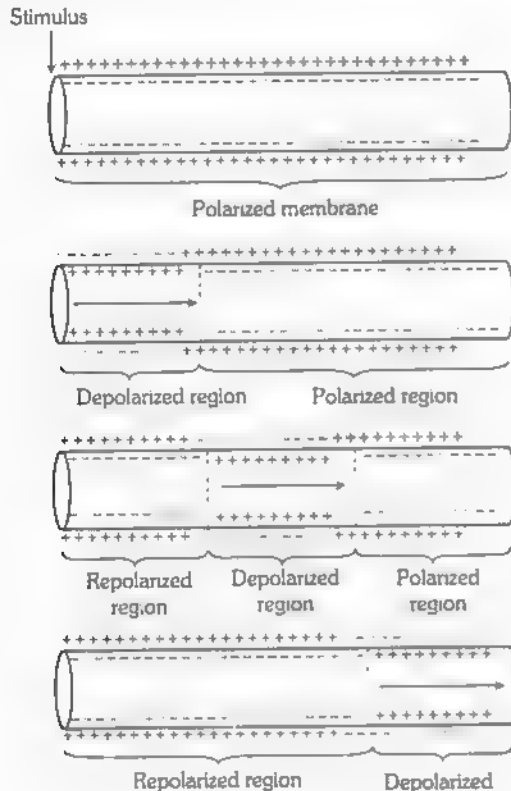


Fig : 5.6-20 Transmission of nerve impulse

(ii) **Depolarization (Action membrane potential or AMP)** : When the nerve fibre is stimulated mechanically, electrically, thermally or chemically a disturbance is felt at the point of stimulation which gives rise to a local excitatory state. The membrane becomes permeable to sodium ions. The membrane is negatively charged on the outside and positively charged on the inside. The membrane with reversed polarity is said to be depolarized. This wave of depolarization travelling down a nerve fibre is called **action potential**. Infact, the action potential "moves" in the manner of a spark moving along a fuse. This "moving" action potential constitutes the **nerve impulse**. The action potential (impulse) is the basic means of communication within the nervous system. The action potential of + 45 mv on inner side of axolemma in respect to its outer side is also called spike potential.

(iii) **Repolarization** : With the increase of sodium ions inside the nerve cell, the membrane becomes less permeable to sodium ions whereas the permeability of the membrane to potassium ions increases. The sodium ions are pumped out of the cell and potassium ions are pumped into the cell until the original resting state of ionic concentration is achieved. Thus this makes the membrane negative on inside and positive on outside. This process is called repolarization.

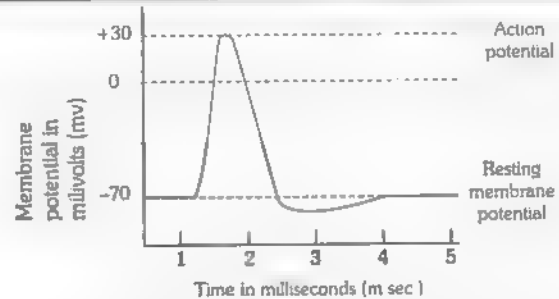


Fig : 5.6-21 Record of potential changes

The last movement of ions is thought to take place by an active transport mechanism called sodium potassium pump (also called sodium potassium exchange pump or sodium pump). The sodium-potassium pump is a process of expelling out sodium ions and drawing in potassium ions against concentration and electrochemical gradient. The entire process of repolarization requires some time during which the nerve cannot be stimulated again. This period is called **refractory period**. During repolarization, as the cell returns to its resting potential, the neuron is ready to receive another stimulus.

**The synapse** : The synapse is an area of functional contact between one neuron and another for the purpose of transferring information. Synapses are usually found between the fine terminal branches of the axon of one neuron and the dendrites or cell body of another. This type of neuron is called axo-dendrite synapse. Sir Charles Sherrington (1861-1954) was the first person who used the term 'synapse' to the junctional points between two neurons.

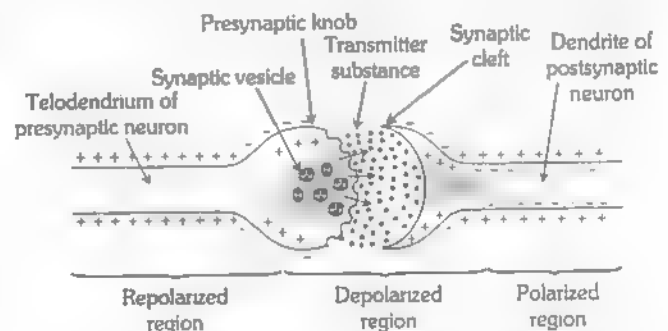


Fig : 5.6-22 Impulse conduction at synapse

(1) **Structure of synapse** : A typical (generalized) synapse consists of a bulbous expansion of a nerve terminal called a pre-synaptic knob lying close to the membrane of a dendrite. The cytoplasm of the synaptic knob contains mitochondria, smooth endoplasmic reticulum, microfilaments and numerous synaptic vesicles. Each vesicle contains neurotransmitter (chemical substance) responsible for the transmission of the nerve impulse across the synapse. The membrane of the synaptic knob nearest the synapse is thickened and forms the presynaptic membrane. The membrane of the dendrite is also thickened and is called the post synaptic membrane. These membranes are separated by a gap, the synaptic cleft. It is about 200 Å across. The post synaptic membrane contains large protein molecules which act as receptor sites for neurotransmitter and numerous channels and pores.

The two main neurotransmitters in vertebrate nervous system are acetylcholine (ACh) and noradrenaline although other neurotransmitters also exist. Acetylcholine (ACh) was the first neurotransmitter to be isolated and obtained by Otto Loewi in 1920 from the endings of parasympathetic neurons of the vagus nerve in frog heart. Neurons releasing acetylcholine are described as cholinergic neurons and those releasing noradrenaline are described as adrenergic neurons.

**(2) Mechanism of transmission of nerve impulse at a synapse :** The process of chemical transmission across synapses was discovered by Henry Dale (1936). The physiological importance of synapse for the transmission of nerve impulses was established by McLennan in 1963. A brief description of the mechanism of synaptic transmission is given below

(i) When an impulse arrives at a presynaptic knob, calcium ions from the synaptic cleft enter the cytoplasm of the presynaptic knob.

(ii) The calcium ions cause the movement of the synaptic vesicles to the surface of the knob. The synaptic vesicles are fused with the presynaptic membrane and get ruptured (exocytosis) to discharge their contents (neurotransmitter) into the synaptic cleft.

(iii) The synaptic vesicles then return to the cytoplasm of the synaptic knob where they are refilled with neurotransmitter.

(iv) The neurotransmitter of the synaptic cleft binds with protein receptor molecules on the post synaptic membrane. This binding action changes the membrane potential of the postsynaptic membrane, opening channels in the membrane and allowing sodium ions to enter the cell. This causes the depolarization and generation of action potential in the post-synaptic membrane. Thus the impulse is transferred to the next neuron.

(v) Having produced a change in the permeability of the postsynaptic membrane the neurotransmitter is immediately lost from the synaptic cleft. In the case of cholinergic synapses, acetylcholine (ACh) is hydrolysed by an enzyme acetylcholinesterase (AChE) which is present in high concentration at the synapse.

(vi) The products of the hydrolysis are acetate and choline which are reabsorbed into the synaptic knob where they are resynthesized into acetylcholine, using energy from ATP.

**Table : 5.6-5 Types and Nature of Neurotransmitters**

S.No.	Excitatory	Inhibitory
1.	Acetylcholine	Gamma amino butyric acid (GABA)
2.	Norepinephrine (NE)	Glycine
3.	Serotonin	
4.	5-hydroxy tryptamine (5-HT)	
5.	Dopamine	
6.	Histamine	
7.	Glutamate	
8.	Epinephrin	
9.	Gastrin	
10.	Glucagon	
11.	Melatonin	
12.	ADH	

**(3) Neurotransmitters :** As explained in the discussion of synapses, neurotransmitters are chemicals released from a presynaptic neuron that interact with specific receptor sites of a postsynaptic neuron. At least sixty chemicals thought to have the capacity to act as neurotransmitters have been discovered.

**Synapse, A one-way valve :** The synapse cannot transmit an impulse in the reverse direction as the dendrites cannot secrete a neurotransmitter. Thus, the synapse acts as a one-way valve, allowing the conduct of impulse from axon to dendron only.

**Synaptic delay :** Transmission of an impulse across a synapse is slower than its conduction along a neuron. This is because of the time needed for the release of a neurotransmitter, its diffusion through the synaptic cleft, and its action on the postsynaptic membrane. The difference in the rate is called synaptic delay. It amounts to about half a millisecond at body temperature (37°C).

**Synaptic fatigue :** It is a temporary suspension of impulse transmission in the region of synapse due to exhaustion of its neurotransmitter. It lasts for several seconds during which the neurotransmitter is resynthesized. Synaptic fatigue is the only fatigue that affects the nervous tissue. Conduction of the nerve impulse along the neurons is not subject to fatigue.

**"All or None law" (Keith Lucas, 1905) :** When stimulated, the axon membrane (= axolemma) does not respond for a moment due to its resistance or threshold to stimulation. However, when its threshold is broken, the stimulation is conducted through its whole length as a strong impulse. If the stimulation is too weak to break the axon's threshold, impulse is not established, but if the intensity of stimulation is much more than the threshold value, impulse conduction remains normal. Thus, the action potential obeys "all or none law". In other words, impulse conduction is such a triggered phenomenon which, though occurs in a twinkling, like an explosion, but only when it reaches "ignition point" or firing level".

## Sense Organs

How are environmental changes detected? In its broadest context, sensation is the conscious or unconscious awareness of external or internal stimuli. Cells which are specialised to receive stimulation are called receptors.

The sensory system consists of simple to complex structures called sensory receptors. An animal responds to a stimulus in a four-step process – sensory transduction, transmission, integration and response.

## Types of receptors

**(1) Exteroreceptors :** Receive stimulation directly from external environment. These may be of following type

- Photoreceptor :** Sensitive to light (Eye)
- Thigmoreceptor :** Sensitive to touch.
- Tectoreceptor :** Sensitive to touch.
- Tangoreceptor :** Sensitive to touch pressure.
- Phonoreceptor :** Sensitive to sound (Ear).

- (vi) **Olfactoreceptor** : Sensitive for smell (Nose).
- (vii) **Gustoreceptor** : Sensitive to taste (Tongue).
- (viii) **Thermoreceptor** : Sensitive to temperature.
- (ix) **Calo receptor** : Sensitive to heat
- (x) **Frigido receptor** : Sensitive to cold.
- (xi) **Galvano receptor** : Sensitive to electric current.
- (xii) **Rheoreceptor** : Sensitive to water or air current.
- (xiii) **Geo receptor** : Sensitive to gravity.
- (xiv) **Telereceptor** : Sensitive to distance. (Receptors of vision, hearing and smell receive stimuli from a distance hence called telereceptor).

(2) **Proprioceptors** : Proprioceptors are located in skeletal muscles, joints, tendons etc. It is from these receptors that we know the position of our arm or leg without having to look at it.

(3) **Intero receptor** : These are present in internal organ. Ex. receptor for hunger, thirst, pain and balancing.

### Few important receptors

#### (1) Important tangoreceptor

(i) **Merckel's corpuscles** : Found in epidermis (stratum malpighi) of skin.

(ii) **Merckel's disk** : Found in epidermis (stratum malpighi) of skin.

(iii) **Meissner's corpuscles** : Present in skin around the base of hair and feather. These are sensitive for touch and pressure both.

(iv) **Genital corpuscles** : These are sensitive cells with nerve endings in skin around the genital organ.

(v) **Grandey's corpuscles** : Found in birds at the base of the beak. These are kidney shaped in structure.

(vi) **Herbert corpuscles** : Found in buccal cavity of birds.

(vii) **Capsulated corpuscles** : These are sensitive cells encapsulated and found in skin.

(viii) **Pacinian corpuscles** : Found in deep layer of dermis and sensitive to pressure

(ix) **Golgi corpuscles and Mazzoni corpuscles** : These are sensitive to touch and found in subcutaneous region.

#### (2) Important Olfactoreceptor

**Jacobson's organ (Vomero-nasal organ)** : It is concerned with smell. These were 1<sup>st</sup> appear in amphibians and well developed in snake, lizard and sphenodon that is reptile. These are less developed in birds and mammal. Structure is blind sac like and lined by olfactory epithelium (Shneiderian membrane). Jacobsons organ is not found in rabbit. In man it is vestigial organ. In human foetus Jacobson organ present. Jacobson organ also found in marsupiales, Rodents, and Insectivora.

#### (3) Important Thermoreceptor

(i) **Krause end bulb** : These are sensitive for temperature and pain and frigido in nature. Found in lips, tongue, conjunctiva of eyes and corium of finger.

(ii) **Organ of Ruffini** : Sensitive to temperature and mainly related with heat.

(iii) **Ampulla of Lorenzini** : Found in snout region of cartilagenous fishes these are helpful in detecting the temperature of water.

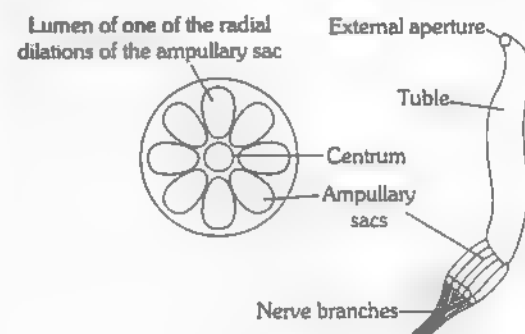


Fig : 5.6-23 Ampulla of Lorenzini

### Eye

Human have binocular vision. The eye can discriminate colour, appraise length, width and depth visually and form true inverted image.

#### Structure of eye

The eyes are two in number and lodged in orbits (bony socket) of skull. The eye is a hollow, spherical organ, about 2.5 cm in diameter and about 6 to 8 gram in weight. It has two parts –

(1) **Protective devices** : Eye has four protective devices.

(i) **Eye brows** : The outwardly directed hair of the eyebrows carry the sweat and rain drops trickling down the forehead to the sides to prevent their falling into the eyes.

(ii) **Eye lids (Palpebrae)** : In man two eyelids are present, upper is movable. They are regularly closed at short intervals to clean the cornea. This is called blinking. In frog out of two upper eyelid is immovable and lower eyelid is movable. Nictitating membrane is present in frog which protect eye in water. Movement of nictitating membrane takes place by retractor bulbi. It becomes folded by levator bulbi.

A nonfunctional vestigial nictitating membrane, called plica semilunaris, occurs in human eyes. It remains permanently retracted at the inner angle of each eye.

(iii) **Eye lashes** : The eyelids bear at the free edge a row of stiff hair, the eye lashes. These check the entry of dust particles, tiny insects and rain drops into the eyes.

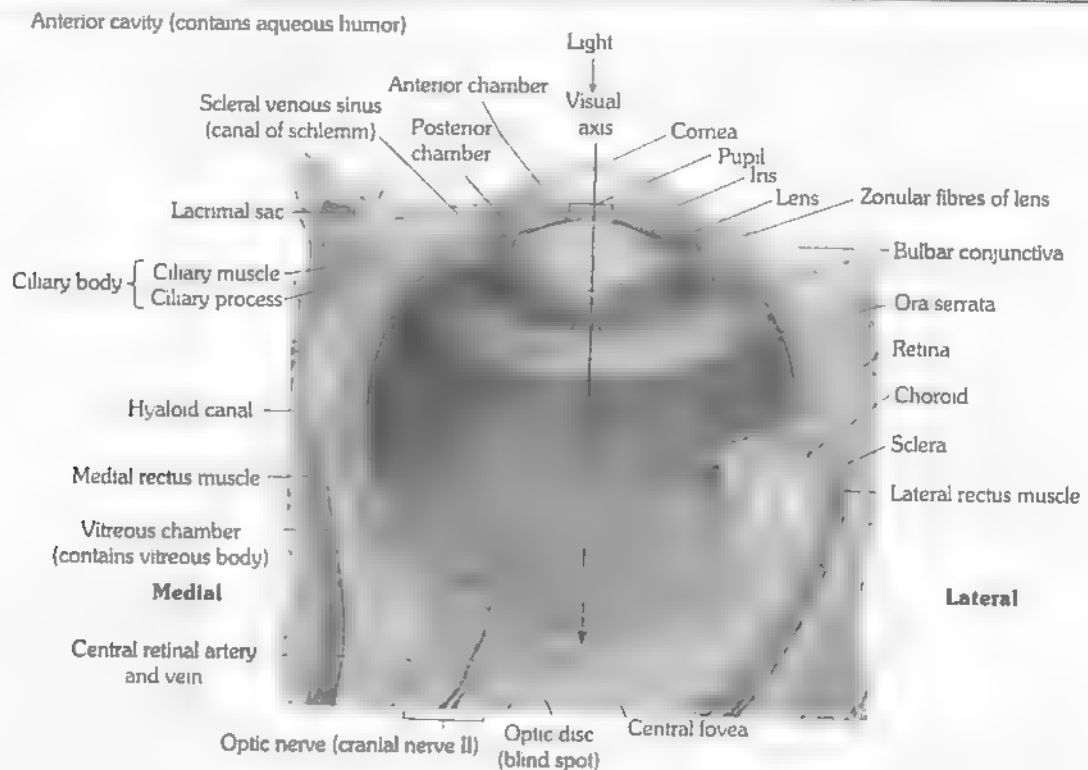


Fig : 5.6-24 Superior view of transverse section of right eyeball

#### (iv) Eye glands

(a) **Meibomian gland** : The eye-lids bear at the free edge a row of meibomian gland that is modified sebaceous gland. (Act as a lubricant).

(b) **Lacrimal gland or Tear gland** : It lies in the upper outer part of the orbit and secretes a slightly saline, watery fluid that contains a bacteriolytic enzyme named lysozyme. This secretion moistens the surface of the eyeball. The excess of this secretion passes through nasolacrimal duct. It is modified sweat gland.

(c) **Harderian gland** : Some aquatic mammals (whale) possess harderian gland which lubricate nictitating membrane. It is also found in frog and birds.

(d) **Glands of zeis (zis)** : These are modified sebaceous gland, found at base of hair follicle of eye lashes, pour lubricating fluid in hair follicle. Infection of these glands is Sty.

(e) **Glands of Moll** : It is modified sweat gland and open into the follicles of eyelashes.

In human meibomian, lacrimal, Moll's glands, and zeis glands are present.

(v) **Connective tissue** : A layer of fatty connective tissue surrounds the eyeball. It serves as a soft shockproof pad.

(2) **Eyeball** : Eyeball is made up of 3 coats or tunic.

(i) **Sclerotic layer (Fibrous tunica)** : Outer most and opaque, fibrous and non-vascular layer easily seen as white of the eye. It is a coat of dense connective tissue made up of collagen fibres and fibroblasts. Sclera covers entire eyeball except cornea, gives shape to eyeball. Sclera in frog is cartilaginous

(a) **Cornea** : In the centre, sclerotic layer it merges with the transparent round window called cornea.

(b) **Conjunctiva** : The cornea and exposed part of sclera are covered externally by a thin, transparent membrane the conjunctiva.

(ii) **Choroid layer (Vascular tunica)** : Also known as uvea middle. It is vascular layer which supplies nutrients to the eye. It is distinguished into three parts choroid, ciliary body and iris.

(a) **Choroid** : It is highly vascular posterior portion of vascular tunic. The choroid occurs in the main part of eyeball adhered to the sclerotic. (The pigment is reddish in rabbit and black, brown or bluish in man).

(b) **Ciliary body** : Ciliary body is vascular and pigmented like choroid, made up of ciliary processes and ciliary muscles (only circular type). The ciliary body is hidden by iris. The ciliary body helps in accommodation by altering the focus of eye from object or the shape of lens near or far vision.

(c) **Iris** : Beyond the ciliary body, the vascular tunic sharply turns inwards, forming a circular, shelf-like diaphragm called iris. The colour of the iris is responsible for colour of eye e.g., brown, black, blue or green. In albinos, iris is deficient of pigments.

**Lens** : Lens is colourless, transparent and fibrous crystalline structure made up of protein ( $\alpha$  and  $\beta$  crystalline protein) and enclosed in lens membrane. It is ectodermal in origin. Lens is lodged in eyeball by suspensory ligament of ciliary body. Suspensory ligaments are known as "Zonula of Zinn". In man lens is biconvex while in frog it is elliptical (subspherical).

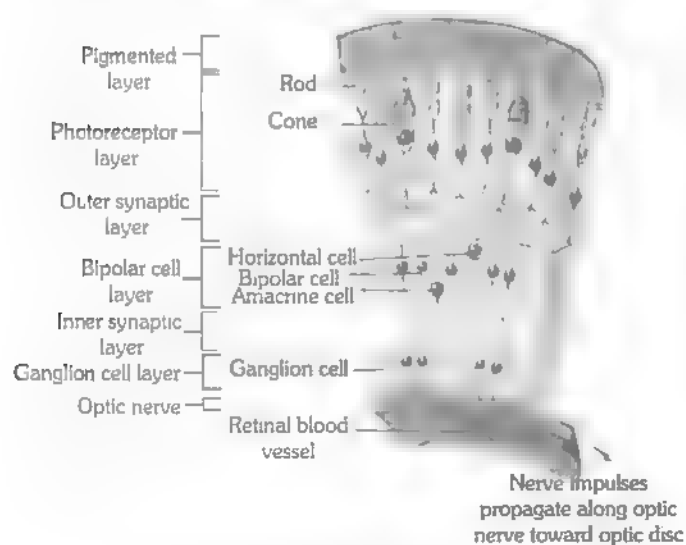
Lens divide the eyeball in 2 chamber outer aqueous chamber (partially divided into a large anterior and a smaller posterior chamber) filled with aqueous humor (watery) formed by ciliary body and inner vitreous chamber filled with vitreous jelly (or Wharton's jelly) containing 99% water, some salt a little mucoprotein (vitrein) and hyaluronic acid.

**Table : 5.6-6 Differences between Aqueous humour and Vitreous humour**

S.No.	Aqueous humour	Vitreous humour
1.	It occurs in aqueous chambers	It occurs in vitreous chamber.
2.	It is a watery fluid	It is a jelly-like substance.
3.	It is secreted by ciliary processes.	It is apparently secreted by retina during development of eye
4.	It is continuously absorbed into blood and replaced.	It is not absorbed or replaced
5.	It contains most of the diffusible substances of the plasma	It consists of water (99%) protein vitrein, hyaluronic acid and collagen fibres.
6.	Obstruction in its flow may damage retina by increasing intraocular pressure	It does not flow.
7.	Refractive Index is 1.33 D	1.34 D

(iii) **Retina (Neurosensory tunica)** : It is innermost, thin and transparent, purplish red due to the presence of the eye pigment rhodopsin (in rods) or visual purple which was extracted by Kuhne (1876) and named 'Schpurpur' (Visual purple). Made up of 4 distinct layer –

- Cuboidal pigmented epithelium (towards choroid).
- Layer of rods and cones
- Layer of bipolar neurons.
- Layer of ganglia (Towards vitreous chamber innermost).



**Fig : 5.6-25 Microscopic structure of the retina**

**Area centralis of retina** : A little part of retina that lies upon the optical axis is called area centralis. Here, the retina is very thin and contains only cone cells filled with a yellow pigment. Hence, this part is called yellow spot or macula lutea. In man (Rabbits) and other mammals, but not in frogs, this area has a small shallow depression called fovea centralis. The later is the most sensitive part of an eye, i.e. the area of most acute vision. It is also claimed that the cone cells in fovea centralis are placed somewhat obliquely. So that these can form magnified images of object.

**Blind spot (Optic disc)** : At this point, the optic nerve turns towards the outer side, pierces through the whole thickness of the wall of eyeball, forming an optic foramen and runs to the brain. Obviously, the region of optic foramen has no retina. It therefore, does not take part in image formation and is called blind spot.

**Table : 5.6-7 Differences between Blind spot and Yellow spot**

Blind spot (Optic disc)	Yellow spot (Macula lutea)
It lies a little away from the yellow spot.	It lies exactly opposite the centre of the cornea.
It contains no pigment.	It has a yellow pigment.
Optic nerve starts from this spot.	No nerve starts from this spot
It lacks a depression.	It has a shallow depression, the fovea centralis, at its middle
It lacks visual receptors and is insensitive to light.	It has visual receptors and is sensitive to light.
The eye coats are absent at blind spot.	Eye coats are present at yellow spot
No image is formed at this place.	Image is formed at this place

**Ora seratta** : The functional retina terminates anteriorly along an irregular border, the ora seratta.

**Table : 5.6-8 Function of the parts of human eye**

Part	Function	Part	Function
Lens	Refracts and focuses light	Ciliary body	Holds lens in place
Iris	Regulates light entrance	Retina	Contains receptors.
Pupil	Admits light.	Rods	Allow black and white vision
Choroid	Absorbs extra light.	Cones	Allow colour vision.
Sclera	Protects	Optic nerve	Transmits impulse
Cornea	Refracts light.	Fovea centralis	Region of cones in retina
Humours	Refracts light.		

### Working of eye

(i) **Mechanism of light perception** : The human eye has two functional parts – Dioptic or Focussing part and Receptor part.

(ii) **Focussing part** : It consists of conjunctiva, cornea, aqueous humour, lens and vitreous humour. These parts are transparent and act as lenses. They refract the light rays passing through the eye to bring them to a focus on the retina. Maximum refraction is caused by the cornea, which places the image approximately on the retina. The lens effects fine adjustment and brings the image into a sharp focus.

(iii) **Receptor part** : It comprises the retina. The image formed on the retina is inverted and smaller. It converts the energy of specific wave lengths of light into action potential in nerve fibre.

(a) **Pathway of sensory impulses from eye to brain** : The nerve impulses generated in the retina of the eye in response to light follow a definitive path and terminate in visual cortex in each optic lobe which act as primary visual center.

### Biochemistry of eye

The receptor cells of eye are called photoreceptor or visual cells. They are of two types – Rod cells and Cone cells.

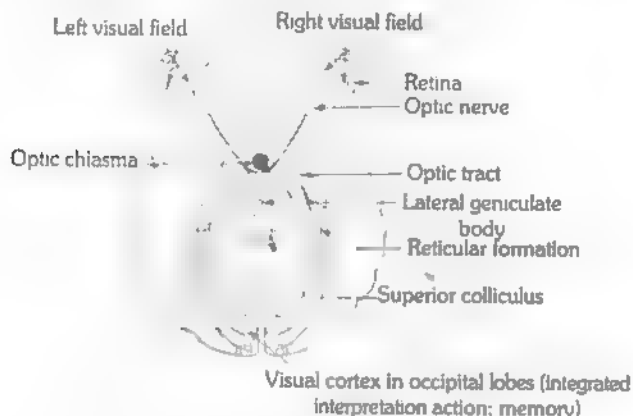


Fig : 5.6-26 Pathway of sensory impulses from eye to brain

(1) **Rod cells** : The rod cells contain a purplish pigment called visual purple or rhodopsin. They function in dim light and at night. They produce poorly defined images. Bright light splits rhodopsin into a lipoprotein scotopsin and a carotenoid pigment retinal (retinine) a process called bleaching. The splitting of rhodopsin depolarizes the rod cell and it releases a neurotransmitter, passing the nerve impulse via bipolar neuron and ganglion cells to the optic nerve. In the dark, rhodopsin is resynthesized from scotopsin and retinal. This process is called 'dark adaptation'. It makes the rods functional. It takes sometime for rhodopsin to be reformed. This is why on entering a dark room at daytime or on coming out of a well lighted room at night we feel blind for a while, when we go from darkness into bright light, we feel difficulty in seeing properly for a moment till rhodopsin is bleached and cones become functional.

(2) **Cone cells** : Cones contain iodopsin which is visual violet and made up of photopsin + retinal. The 3 types of cones are erythrolabe (775 nm sensitive to red), cyanolabe (430 nm sensitive to blue) and chlorolabe (sensitive to green 535 nm). However, if all the cone types are simultaneously stimulated by equal amounts of coloured light then sensation for white light is perceived.

Diurnal animals are adapted to see during day light (Photopic vision) and can perceive colour. In dark, colours are not perceived. Such animals have more cones in their eye than rods.

Table : 5.6-9 Differences between Rod cells and Cone cells

Rod cells	Cone cells
Rods secreted by rod cells.	Cones secreted by cone cells
Produce "Rhodopsin" which is visual purple and made up of scotopsin + 11 cis retinal. Vitamin-A is needed for the formation of Rhodopsin.	Produce "Iodopsin" which is visual violet and made up of photopsin + 11 cis retinal.
Rhodopsin is very sensitive to light	It is sensitive to colour.
Rods are active in dim light or low intensity light	Cones are active in bright light which is called photopic vision
Rod cells are absent in fovea centralis of retina.	In fovea centralis only cone cells are present.
Rods are more in number in peripheral region of retina.	Cones are more in number in central region of retina
Rods are more in nocturnal animals	Cones are more in diurnal animals
In owl only rods are present and cones are absent	In fowls only cones are present and rods are absent
120 million rods in human	6 million cones in human

### Accommodation and types of vision

(1) **Accommodation** : Light passes through many refractive surfaces before it is focussed on the retina forming an inverted and true image. The main sites of refraction are cornea → aqueous humor – iris – lens (position can be altered by ciliary body accommodation) – posterior chamber (= vitreous humor) → retina (in fovea). The refractive index of the eye varies from 59 diopter (when the lens is at rest) to about 71 diopter (when lens is bulging in maximum accommodation). The accommodation reflex occurs when the eye changes its focus from a far away object to nearer one. The change in strength of the lens provides the physiological basis of accommodation. Radial and circular muscle fibres of ciliary muscles play an important role in this as they contract reflexively (parasympathetic control) and increase lens strength. The pupil constricts. This facilitates increase in sharpness of image. Ageing causes loss of accommodation.

Table : 5.6-10 Relationship between structures during accommodation

Object	Ciliary muscle	Suspensory ligament	Lens	Refraction
Near	Contracted	No tension (Relaxed)	Thick	Increased
Distant	Relaxed	Tension maximum	Thin	Decreased

**(2) Types of vision**

(i) **Binocular vision** : Man has binocular vision in which both the eyes are focussed on the same object but from slightly different angles. The visual fields of both eyes overlap and the foveae of both are focused on the same object. This provides depth to the images, i.e., gives stereoscopic or 3D effect and enables man to judge distances correctly.

(ii) **Vision in other animals** : Primates and predatory animals, such as owl and cat, have binocular vision. In some animals, such as rabbit, birds, each eye is focussed on a separate object. This is termed monocular vision.

(iii) **Colour vision** : It is the ability of some animals to detect colours in an object. Humans, apes, monkeys, and most fishes, amphibians, reptiles and birds have strong colour vision. The insects and crayfish also have colour vision. In vertebrates, colour vision results from the activity of cone cells. Most domestic and nocturnal mammals and sharks lack colour vision. They probably see objects in shades of grey (monochrome vision).

(iv) **Nocturnal and Diurnal vision** : Man has both day vision and night vision as he has both rods and cones in considerable numbers in the retina. Most birds have only day vision as their retina contains mainly cones. Owls have much better night vision than day vision for they possess a large number of rods and few cones in their retina.

**Range of vision** : The visible range of spectrum varies in animals. Bees, ants, spiders and goldfish can see ultraviolet light, which is invisible to man.

**Table : 5.6-11 Correspondence between Camera and Eye**

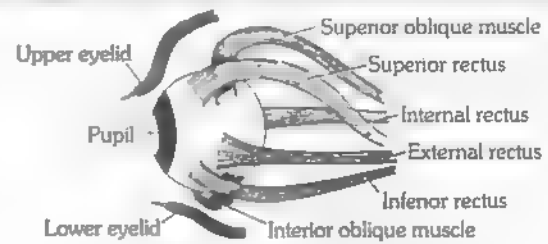
S.No.	Camera	Eye
1.	Box	Sclera
2.	Black inner paint	Choroid
3.	Shutter	Eyelids
4.	Diaphragm	Iris
5.	Light hole	Pupil
6.	Lens	Lens
7.	Light-sensitive plate or film	Retina
8.	Image small and inverted	Image small and inverted

**Eye movement**

In eye orbit eyeball remain attached with 6 extrinsic muscles.

Out of six, first four are rectus and last two are oblique muscles.

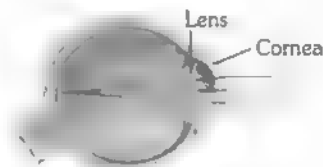
- (1) Anterior rectus or Internal rectus
- (2) Posterior rectus or External rectus
- (3) Inferior rectus
- (4) Superior rectus
- (5) Inferior oblique muscle
- (6) Superior oblique muscle



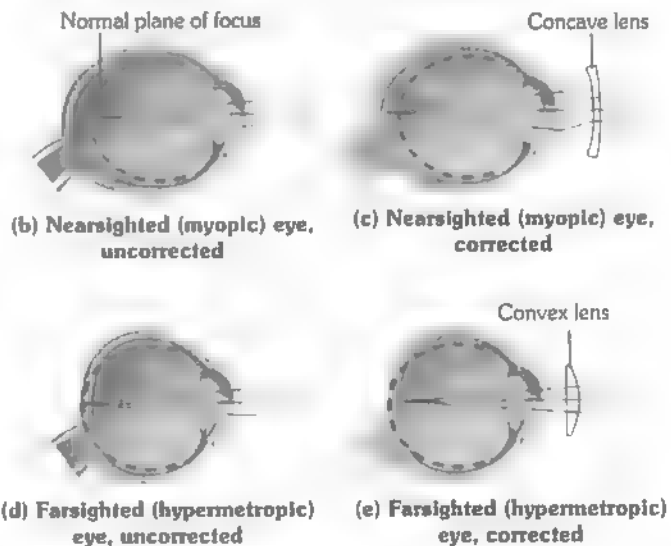
**Fig : 5.6-27 Extrinsic muscles of eyeball**

**Eye defects****(1) Myopia (Short or Near-sightedness)**

- (i) Near object is clear. Far object is not clear.
- (ii) Eyeball become longer.
- (iii) Image is formed before retina. Can be removed by concave lens.



**(a) Normal (emmetropic) eye**



**Fig : 5.6-28 Diagrammatic representation of eye defects**

**(2) Hypermetropia (Long or Far sightedness)**

- (i) Far object is clear, near object is not clear.
  - (ii) Eyeball become short.
  - (iii) Image is formed behind the retina.
  - (iv) Can be removed by convex lens.
- (3) Astigmatism**
- (i) Curvature of cornea become irregular and image is not clearly form.
  - (ii) Can be removed by cylindrical lens.



**(4) Cataract**

- (i) It is due to defective protein metabolism.
- (ii) During this lens or cornea sometime both become opaque.
- (iii) Operation is needed.

**(5) Glaucoma**

- (i) It is due to increase in intraocular pressure in aqueous chamber.
- (ii) Operation is needed at early stage due to blockage of schlemm's canal.

**(6) Trachoma**

- (i) It is increased in redness of eye and more secretion of watery fluid.
- (ii) It is due to infection of bacteria, chlamydia trachomatis.
- (iii) Due to this follicles may form in conjunctiva.

**(7) Xerophthalmia**

- (i) It is due to deficiency of vitamin A. ( $A_2$ )
- (ii) During this conjunctiva or cornea becomes keratinized.
- (iii) It may lead to blindness.

**(8) Strabismus**

- (i) In this type eyeball remain in some what in bended position.
- (ii) It is due to long extra ocular muscles during development of eye.
- (iii) Operation is needed at early stage.
- (iv) Also associated with squint.

**(9) Presbyopia**

- (i) During this power of accommodation of lens decreases due to age factor and defected metabolism.
- (ii) Also known as age sightness.
- (iii) Can be removed by bifocal lens.

**(10) Photophobia** : No clear image in bright light.**(11) Emmetropia** : Normal vision.

## Phonoreceptor and Mechanism of hearing or auditory sensations and equilibrium

Also known as stato-acoustic organ. It is the receptor for balancing and hearing which is sensitive for gravity and sound waves. It is also sensitive in orientation of body. It is also known as mechano receptor because of it change mechanical energy of sound waves into action potential.

### Structure of Ear

Ear of mammal is divided into 3 parts –

- (1) **External ear** : It is made up of pinna and auditory meatus. Pinna is found in only mammals. Its upper rounded part is

helix and lower is ear lobe. It is made up of adipose connective tissue and elastic cartilage and has ear muscles which are vestigial in case of human beings. Pinna collect the sound waves and drive towards auditory meatus.

Auditory meatus is 25 mm. long canal lined by simple columnar epithelia and made up of fibro elastic cartilage. It possesses ceruminous gland which secrete cerumin (ear wax). Cerumin trap the dust particles and microbes.

**Tympanic membrane** : It is also called ear drum and present at the junction of auditory meatus and tympanic cavity.

(2) **Middle ear** : The cavity of middle ear is known as tympanic cavity which is enclosed by tympanic bulla bone of skull and filled with air. Middle ear separated from external ear by ear drum and from internal ear by thin bony portion or partition with two openings known as oval and round window.

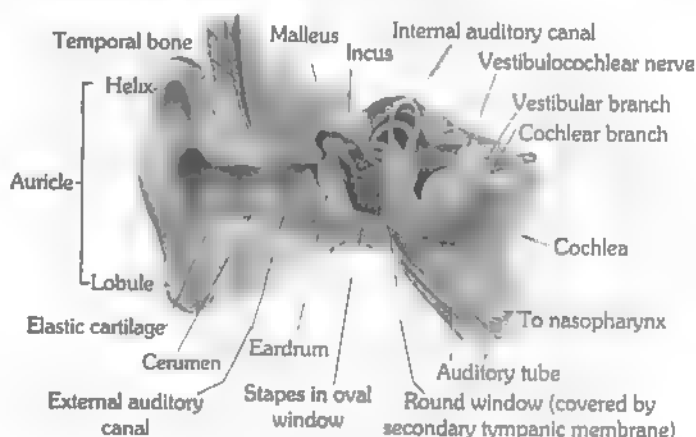


Fig : 5.6-29 Right Internal ear

(i) **Ear ossicle** : A chain of three small, movable bones, the auditory or ear ossicles crosses the tympanic cavity. The outer ossicle is attached to the inner surface of the tympanic membrane.

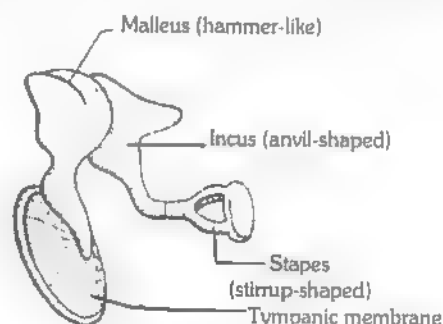


Fig : 5.6-30 Ear ossicles

Table : 5.6-12 Ear ossicles

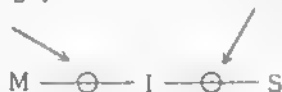
Ear ossicle	Shape	Modification of
M – Malleus	Hammer shaped	Articular bone of lower jaw.
I – Incus	Anvil shaped	Quadrate bone
S – Stapes	Stirrup shaped	Hyomandibular of columella

In man ear ossicles are known as H.A.S. stapes is the smallest bone of the body. In frog only stapes is present.

### (ii) Joints

Synovial hinge joint

Ball and socket joint



### (iii) Muscles

**Tensor tympani** : Limits movements and increases tension on eardrum to prevent damage to inner ear from loud sound.

**(iv) Eustachian tube** : It is made up of elastic cartilage and it connects middle ear to nasopharynx. It maintain equilibrium in and out side of the tympanic membrane. Blocking of eustachian tube impairs hearing due to imperfect vibrations of drum. Eustachian tube is normally closed, it opens during swallowing and yawning.

**(v) Fenestrae** : Between middle ear and internal ear a thin bony membrane is present which possess two apertures (Windows).

**(a) Fenestra ovalis** : It is upper window, connect middle ear to internal ear and guarded by membrane. End of stapes is fit on the upper window. It is towards vestibule so it is also known as *F. vestibuli*.

**(b) Fenestra rotundus** : It is ventral window, connect middle ear to internal ear and guarded by membrane. It is towards scala tympani so it is also known as *F. Tympani* (also known as *F. cochleae*).

**(3) Internal ear (Membranous labyrinth)** : Internal ear is also known as membranous labyrinth and enclosed by bony labyrinth. Bony labyrinth is formed by petrous bone or petrous. A cavity is present between membranous labyrinth and bony labyrinth known as perilymphatic space. It is filled with perilymph and endolymph is found in membranous labyrinth. The membranous labyrinth consists of 2 parts – Vestibule and Cochlea.

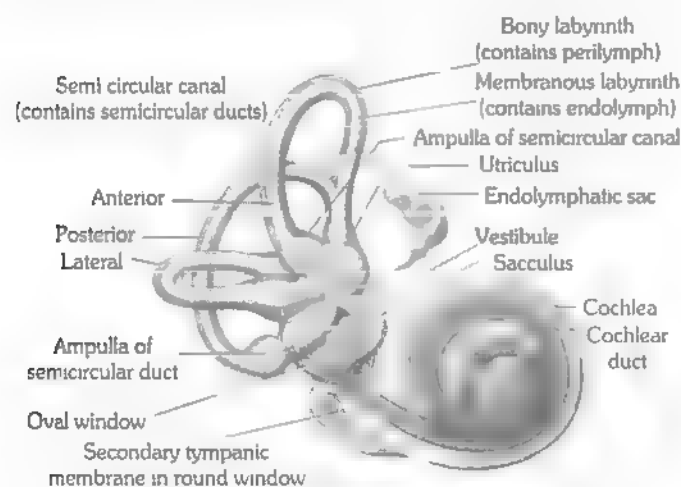


Fig : 5.6-31 Section through the cochlea (Semicircular canals, vestibule and cochlea of the right ear)

**(i) Vestibule** : The vestibule is a central sac like part. It further consists of 2 chambers large – Utriculus (Upper) and smaller – sacculus (lower).

**(a) Semicircular canal** : From utriculus 3 semicircular canals arise these are –

Anterior semicircular canal (Superior)

Posterior semicircular canal (Inferior)

Horizontal semicircular canal (External)

They are perpendicular each other.

**Crus commune** : A common part of anterior and posterior semicircular canal arising from dorsal region of utriculus is known as crus commune.

**Ampulla** : Terminal part of the each semicircular canal is enlarged to form an ampulla.

**Crista** : Each ampulla has a sensory spot called crista ampullaris or simply crista, for equilibrium.

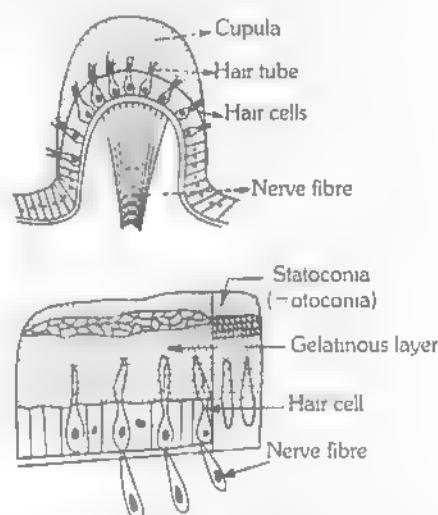


Fig : 5.6-32 Crista and macula of ear

**(b) Sacculus** : It is a lower chamber of vestibule. From the lower part of the sacculus arises a short tube, the ductus reuniens, that joins the cochlear duct.

**Ductus endolymphaticus** : It is filled with endolymph and arises from the junction of utriculus and sacculus.

**Macula** : are present in utriculus and sacculus. it is a group of sensory cells. In man (Rabbit) 2 maculas are present. (A crista resembles a macula in structure except that lies on an elevation, the acoustic ridge, its sensory cells have longer "hair", and its gelatinous mass is dome shaped, lacks otoliths and is called cupula )

Table : 5.6-13 Difference between Crista and Macula

S.No.	Crista	Macula
1.	Found in ampulla of semi-circular canal	Found in vestibule i.e sacculus and utriculus.
2.	Their total number is 3	Only 2 are present
3.	No otolith	Otolith present
4.	Long auditory hairs	Short auditory hair
5.	Facilitate maintenance of dynamic equilibrium and angular acceleration e.g. rotational movement of head	Help in static equilibrium and linear acceleration e.g. tilting of head or body at rest and rapid forward movement

**Otolith** : Also known as otoconia made up of protein and calcium carbonate and present in endolymph.

(ii) **Cochlear duct and Cochlea** : It is a spirally coiled tube (2 – 3 coiling) which is connected to sacculus by a short duct. It is divided into 3 chambers by 2 membranes.

(a) **Scala vestibuli** : Upper chamber filled with – perilymph - connect with middle ear by *F. ovalis*, or oval window.

(b) **Scala media (Real cochlear duct)** : Middle chamber filled with – endolymph.

(c) **Scala tympani** : Lower chamber filled with – perilymph connect with middle ear by *F. Tympani* or round window.

(d) **Reissner's membrane** : Present at the roof of scala media, it separate S.M. to S.V.

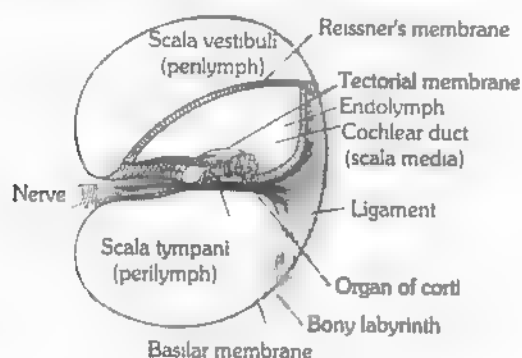


Fig : 5.6-33 Cochlear apparatus in T.S.

(e) **Basilar membrane** : Present at the base of S.M. It is thicker than Reissner's membrane and it separates S.M. to S.T.

(f) **Modiolus** : A bony core around which bony spiral canal of cochlea make  $2\frac{3}{4}$  turns or coils in man.

(g) **Helicotrema** : A aperture present in scala media which connect scala vestibuli to scala tympani is known as helicotrema.

(h) **Tectorial membrane** : Tectorial membrane is a leaf like gelatinous structure present at the dorsal side of organ of corti.

(i) **Organ of corti** : Discovered by Italian anatomist Alfonso-Corti. Also known as ridges of corti which are present in basilar membrane. Organ of Corti contains a variety of cells. They receives nutrients from endolymph. The cells of organ of Corti are following types –

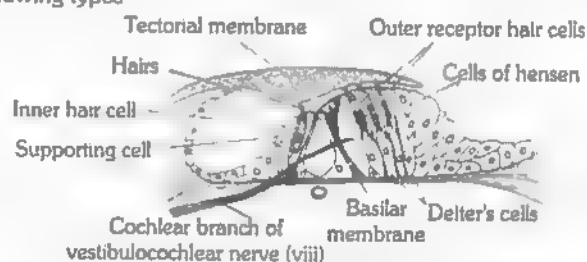


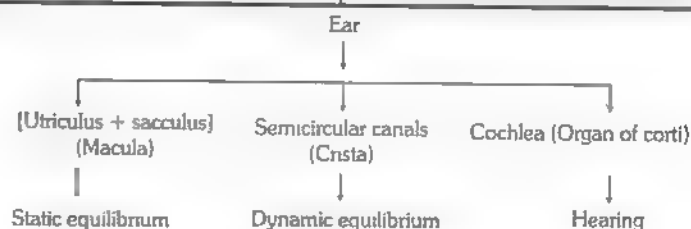
Fig : 5.6-34 Detailed structure of organ of corti (vertical section)

Table : 5.6-14 Characteristics of cells of organs of Corti

Receptor cell (=Hair cells)	Supporting cells	Tectorial membrane	Peripheral membrane
Two type (i)- inner hair cells – in one layer and number 3500, while the (ii) outer hair cells are in 3 – 4 rows (20,000)	Support hair cells. These rest on basilar membrane	Flap of fibrous and gelatinous tissue, the outer right plate is called reticular lamina which is supported by rods or corti anchored to basilar membrane	Has restricted elasticity respond to low to high frequencies within audible region
Hair of outer hair cell extend into scala media and embeded in roof like tectorial membrane.	Provide nutrients and physical support to the hair cells		
Inner hair cells respond to the velocity of movement of the basilar membrane. While the outer hair cells are primarily concerned with the displacement of the basilar membrane by the sound waves.	They are not involved in sound transduction		
Hair cells have a basal body just under the hair. The basal body facilitates transduction of the mechanical signal to a neural signal (electrogenesis)			

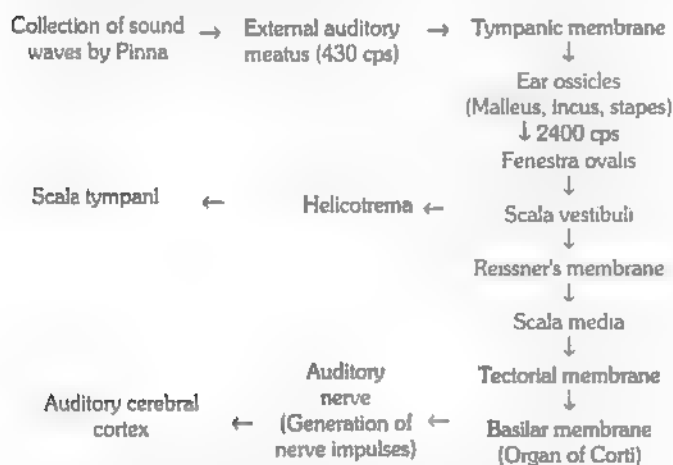
### Mechanism of sound perception

Vone Beskey won the Nobel prize for his work on ear. The mechanism found in ear involve two unrelated functions : Hearing and equilibrium.



(1) **Hearing** : The ear not only detects sound but also notes its direction, judges its loudness and determines its pitch (frequency). Sound waves are collected by the pinna and directed inward through the external auditory meatus (frequency 430 cycle per second). Here they strike the tympanic membrane. The latter begins to vibrate at the same frequency as that of the sound waves. From the tympanic membrane, the vibration are transmitted across the tympanic cavity by the ear ossicles to the membrane of the fenestra ovalis. The force of vibrations is considerably increased in the middle ear by leverage of the ossicles and also by much smaller surface area of the membrane of fenestra ovalis than that of the tympanic membrane. (The frequency is 2400 cycle/sec). Increase in frequency is important because the sound wave are transmitted from air to a fluid medium. The membrane of fenestra ovalis transmits the vibrations to the perilymph of the scala vestibuli and hence via Reissner's membrane to the endolymph in the scala media. From here the vibrations are transferred to the basilar membrane and the perilymph in the scala tympani.

Vibration of the endolymph of the scala media cause the basilar membrane of this chamber vibrate. Vibrations of the basilar membrane make the "sensory hair" of receptor cells in the organ of corti move in the overlying gelatinous membrane (Tectorial membrane) and get distorted. This stimulation causes depolarisation of the receptor cells and initiation of nerve impulse in the fibres of the auditory nerve. The nerve impulse travels via relay centers e.g. spiral ganglion → cochlear nuclei → superior auditory nuclei → inferior colliculi → auditory cortex of cerebrum (The cerebral cortex interprets the impulses as sound). The various steps in the mechanism of hearing



Human ear can hear a frequency of 500 to 5000 hertz (Hz; 1 Hz = 1 cycle/second). However, it can hear the complete range of frequencies from 20 – 20,000 Hz only with intense sound. Sound energy is measured in terms of units called decibels (dB). Sounds in our city homes average 40 – 50 dB, but street noise averages 70 – 80 dB. Sounds upto 80 dB are considered bearable by man, but higher sound intensity are hazardous, causing nervous stress, irritability, increased blood pressure etc. Non stop noise of 90 or more dB produces temporary deafness. 160 dB sound can cause total deafness by rupturing our ear drum. Sound becomes uncomfortable to normal ear at about 120 dB.

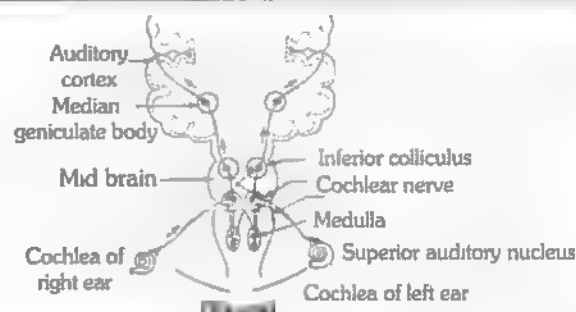


Fig : 5.6-35 Pathway of sound perception from organ of corti in cochlea to auditory cortex of cerebrum

(2) **Equilibrium** : Sound become painful above 140 dB. Exposure to certain antibiotics, such as gentamycin some anticancer drugs, loud sound, loud music, or engine rear of jet planes, vacuum cleaners, damages hair cells of cochlea.

(i) **Static equilibrium and linear acceleration** : Maculae detect changes in the head (or body) with respect to gravity (static equilibrium) and in the movement in one direction (linear acceleration). With a change in the position of the body, the otoliths, being heavier than the endolymph, press upon the sensory hairs of the maculae. This stimulates the sensory cells which initiates nerve impulse in the fibres of the auditory nerve. The macula of utricle responds to vertical movements of the head, and the macula of saccule responds to lateral (sideways) movement of the head

On rapid forward movement, the otoliths, because of having greater inertia than the surrounding endolymph, lag behind and press back the sensory hair, stimulating the sensory cells to generate nerve impulses.

(ii) **Dynamic equilibrium** : Cristae detect turning or rotational movements of the head (angular acceleration). When the head is turned, the endolymph in the semicircular ducts, due to its inertia, does not move as fast as the head and the sensory cells of the crista, but continues to move after the head stops moving. Because of this difference in the rate of movement, the sensory hair of the cristae are swept through the endolymph and become bent over. This disturbance stimulates the sensory cells and sets up action potential in the fibres of the auditory nerve, which transmits it to the brain. Since the three semicircular ducts are arranged in three different planes, a movement of the head in any direction will stimulate the sensory cells of at least one crista.

### Defects of ear

- (1) **Labyrinthine disease** : Malfunction of inner ear.
- (2) **Meniere's disease** : Loss of hearing due to defect in cochlea.
- (3) **Otitis media** : Acute infection of middle ear.
- (4) **Eustachitis** : Inflammation of eustachian tube.
- (5) **Myringitis (Tympanitis)** : Inflammation of eardrum.
- (6) **Otalgia** : Earache (pain in ear)

## Tips & Tricks

- ✎ Tela choroidea is the term used for epithalamus and pia mater fused.
- ✎ Tela choroidea is made up of epithelium and blood vessels.
- ✎ Ataxia means lacks of muscle coordination. Damage to cerebellum is characterized by ataxia.
- ✎ Dyslexia involves an inability of an individual to comprehend written language.
- ✎ Multiple sclerosis is the destruction of myelin sheath of neurons of CNS.
- ✎ An American scientist Roger Sperry got Nobel Prize in 1981 for his outstanding work on split brain theory.
- ✎ Parkinson's disease or Paralysis agitans is a defect of brain.
- ✎ Parkinsonism is characterised by tremors and progressive rigidity of limbs caused by a degeneration of brain neurons and a neurotransmitter called dopamine.
- ✎ Avian brain has large sized optic lobes to see the objects on the earth while flying so is called eye brain, while fish brain has large sized olfactory lobes to smell the prey from a distance so is called nose brain.
- ✎ In fishes : Cerebrum is not differentiated in two cerebral hemispheres.
- ✎ Hypothalamus has additional lobes to note pressure changes.
- ✎ In reptilian brain, pineal eye (parietal body) present in front of pineal body.
- ✎ Grey matter of spinal cord of frog is rectangular while it is butterfly-shaped in mammals.
- ✎ Central canal : Cavity of spinal cord.
- ✎ Optic bigemina : Two optic lobes in brain and are found from fishes to birds.
- ✎ Optic lobes of man are solid and have no optocoel but those of frog have optocoel.
- ✎ Optic tectum : Dorsal thick wall of optic lobe.
- ✎ Cerebellum is also called little brain.
- ✎ Thalami of diencephalon act as relay centres as well as gate keepers of brain.
- ✎ Optic chiasma is meant for binocular vision.
- ✎ Olfactory lobes of human brain have no rhinocoel while those of frog have rhinocoel.
- ✎ Man and birds are less dependent upon smell so olfactory lobes are small sized but are large sized in cartilage fishes (dog fish), dogs and reptiles are more dependent upon smell.
- ✎ Cerebellum is large sized in fishes, birds and rabbit due to their multidirectional movements and increased dependency on balance.

✎ Stimulus for hunger : In February 1998, an American scientist Dr. Masashi Yanagisawa reported that a drop of sugar level in blood stimulates the appetite centres of lateral hypothalamus to release oraxin hormone (Gr. Oraxis = hunger) which stimulates hunger.

### ✎ Nervous disorders

Agnosia : Failure to recognize;

Alexia : Failure to read;

Agraphia : Failure to write;

Aphasia : Failure to speak (due to injury to Broca's area)

Analgesia : Loss of sensation of pain;

Anesthesia : Loss of feeling;

Insomnia : Inability to sleep;

Amnesia : Partial or complete loss of memory;

Coma : Complete loss of consciousness.

Aproxia : Inability to carry out purposeful movements.

Multiple sclerosis : Progressive degenerative disease of CNS and is characterized by many hard scar tissues.

✎ Brain stem : Diencephalon + mid brain + pons + medulla oblongata.

✎ Cerebro vascular accident (C.V.A) or stroke : Blocking of blood supply of a part of brain.

✎ Alzheimer : It is the disease appearing usually after 65 year. It is characterized by dementia usually. Usually in this disease ACh producing neurons of cerebral cortex and hippocampal lobe are degenerated. It is also seen that a amyloid protein is accumulated in the brain. It is the matter of research.

✎ Commissure : The band of nerve fibres between two similar ganglia.

✎ Associate fibres : If joining fibre are joining two similar structure in same halves then, they are called associate fibre.

✎ The rate of conduction in myelinated fibre of a mammal is very high because action potential jumps from node to node.

✎ The jumping of action potential from node to node (of Ranvier) in a fibre is called saltatory conduction.

✎ Nissl's or trigoid granules are present in the neuron and are made up of RNA, ribosome and RER. These granules help in excretion and nutrition.

✎ Intelligence quotient (I.Q.) is the ratio of mental age to chronological age multiplied by 100.

✎ Corpora striata, genu and splenium is found in cerebrum.

✎ Neurons stops dividing after birth.

✎ Optocoel is not found in mammalian brain.

✎ The pneumotaxic centre is found in pons.

✎ Transmission of nerve impulse can be recorded with the help of oscilloscope.

✎ The ramus communicans of the spinal nerve joins the sympathetic chain.

✎ Autonomous nervous system has paired chain ganglia.

✎ Paralysis of jaw muscles is due to loss of function of Vth cranial nerve.

✎ Bipolar nerve cell and ganglia cell are found in the retina.

✎ Arbor vitae are composed of white matter.

- ✎ IIIrd, IVth and Vth cranial nerves control eye-ball movement.
- ✎ A cavity in the ventricle of a brain is known as cerebral aqua.
- ✎ VII, IX, X, XI and XIIth cranial nerve originates from medulla oblongata.
- ✎ Cycling is an example of conditioned reflex.
- ✎ The ganglia of sympathetic and central nervous system in frog develops from the neural crest cells.
- ✎ Cerebellum of post brain involved in loss of control when a person drinks alcohol.
- ✎ The maximum current required to stimulate a nerve is called rheobase or threshold current or firing level of impulse. It is about 15 mv.
- ✎ Earthworm has both sensory and motor neurons.
- ✎ The glial cells that form the blood brain barrier by lining brain capillaries are the astrocytes.
- ✎ Axo-axonic is the condition when direction of nerve impulse is reversed.
- ✎ Unipolar nerve cells are found in vertebrates embryo.
- ✎ Saltatory conduction is found in all vertebrates
- ✎ Corpus callosum is absent in the brain of prototherians and metatherians both
- ✎ Degeneration or imperfect development of corpus callosum in human brain results in a neurological disorder called schizophrenia.
- ✎  $\gamma$ -amino butyric acid is a neurotransmitter.
- ✎ Acetylcholine is the cardiac inhibitor.
- ✎ 5-Hydroxy tryptamine is a chemical transmitter.
- ✎ Spike phase of action potential is 2 m. sec.
- ✎ Sylvian fissure divides the brain of rabbit into frontal lobe and temporal lobe.
- ✎ Dorsal root has the ganglion made of pseudounipolar neurons.
- ✎ All cell bodies of afferent fibres lie in the dorsal root ganglion.
- ✎ EEG - Electro-Encephalogram : Electrical tracing of the cerebral cortex is call EEG Berger in 1929 was first to record EEG Instrument for the recording is Electroencephalograph or cathode ray oscilloscope.
- ✎ It is record of brain wave. Brain waves are of following type
  - (i)  $\alpha$ -wave : These are rhythmic waves (8-13 cycles per second. These are produced in normal awaking condition. These disappear in sleep.
  - (ii)  $\beta$ -wave ; 14-30 cycle per second. These are produced when nervous system is active e.g. Mental work.
  - (iii)  $\theta$ -wave : 5-8 cycle per second. Produced in children.
  - (iv)  $\delta$ -wave : 1-5 cycle per second. In normal condition these are produced in awake infants. These are produced in deep sleep. In damage condition of the brain waves may produce in awaking condition in adults.
- ✎ Fundamental character of chordates is the presence of dorsal hollow nerve chord.
- ✎ Somesthetic & taste area present in parietal lobe of cerebrum.
- ✎ Epilepsy : Is second common neurological disorder is characterized by short, recurrent, periodic attacks of motor, sensory, or psychological mal function. The attacks called epileptic seizures are initiated by abnormal, synchronus electrical discharge from millions of Neurons in brain. Due to this, a person undergoing an attack may contract skeletal muscles involuntarily, light, noise, smells may be sensed when eyes, ears, nose have not been stimulated. Epilepsy has causes, including brain damage at birth (Most common cause), hypoglycemia, hypocalcaemia, hypoxia, uremia, encephalitis, meningitis, and tumors.
- ✎ Nystagmus – An uncontrolled oscillation of the eyes, is one of the symptoms of an inner-ear disease called Meniere's disease (from Prosper Meniere, French physician, 1799-1862).
- ✎ Cones are absent in nocturnal animals like shrews, hedge hogs, rodents and bats.
- ✎ During night the eyes of carnivores like cat, dog, lion, seal glow. It is due to tapetum lucidum a reflecting layer next to retina, which is made of crystalline layer with zinc, cysteine and guanine.
- ✎ Bees can see ultraviolet light
- ✎ The normal eye is known as emmetropic.
- ✎ Deer has biggest eyes in proportion to body size.
- ✎ Except rabbit and man, harderian glands are found in whale, mice, shrews and in reptiles.
- ✎ Nocturnal animals have more rods than cones in their eye. The image formed has no colour but is black or grey, the edges are not sharp.
- ✎ Colour blindness – It is known as daltonism. It is in between red and green colour. It is genetic defect.
- ✎ Colour vision is due to presence of specialise cone cell in Retina which value the sensitivity for different colours.
- ✎ Night blindness – During this rhodopsin is not resynthesized or regenerate in dim light.
- ✎ Monocular vision found in frog, rabbit and horse.
- ✎ Binocular vision found in primates, ape, monkey
- ✎ Colour vision found in fishes, reptiles, amphibia.
- ✎ Sty – Sebaceous gland infection leading to its inflammation
- ✎ There are only four basic modalities of taste, which are sensed most acutely in particular regions of the tongue. These are sweet (tip of the tongue), sour (sides of the tongue), bitter (back of the tongue) and salty (over most of the tongue.)
- ✎ Iris is the third portion of the vascular tunic
- ✎ Atropine is a chemical used by doctors to dilate the pupil before testing.
- ✎ Photopic vision is associated with cones.
- ✎ Cornea grafting : Cornea can be removed from a dead man's eyes, stored and grafted on another person's eye to restore vision, cornea transplantation is successful because it lacks blood vessels. Eye donation is a noble act.



## Ordinary Thinking

### Objective Questions -

#### Development of central nervous system in human

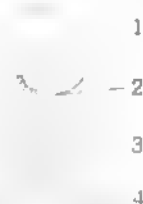
- Which one of the following is essential for the formation of myelin sheath [CBSE PMT 1990]
  - Zinc
  - Sodium
  - Iron
  - Phosphorus
- Mammalian brain differs from an amphibian brain in possessing [CPMT 1993; AFMC 1999; BHU 2008]
  - Olfactory lobe
  - Hypothalamus
  - Corpus callosum
  - Cerebellum
- Brain is [MP PMT 1994, 97, 2006; CPMT 1995, 98; RPMT 1995, 99, 2000, 06; Odisha JEE 2010]
  - Ectodermal
  - Mesodermal
  - Endodermal
  - Mesendodermal
- Which cell stops dividing after birth [MP PMT 1997]
 

Or

 Largest cell in body is [CPMT 1992, 93]
  - Neuron
  - Glial
  - Epithelium
  - Liver
- The second cranial nerve in human originates from
 

Or

 The second cranial nerve of frog is distributed in
  - Ciliary muscles of eye
  - Retina only
  - Retina and lens
  - Ocular muscles of eye
- The ganglia of sympathetic and the central nervous system in frog develops from the [AIIMS 2002]
  - Neural cell
  - Notochordal cells
  - Neural plate cells
  - Neural crest cells
- Which is activated in stress condition [DPMT 2003]
  - Sympathetic
  - Parasympathetic
  - Somatic
  - Whole ANS
- The autonomic nervous system has control over [Kerala CET 2003; MP PMT 2007]
  - Reflex action
  - Skeletal muscles
  - Sense organs
  - Internal organs
- The given diagram indicates part of the human body, the structures belonging to the central nervous system are numbered
 



- 3 and 4
- 1 and 4
- 2 and 3
- 1 and 3

#### Parts of nervous system

- In man which one of the following cranial nerve is associated with the sense of body balance [MP PMT 1992]
  - VI
  - VII
  - VIII
  - IX
- How many pairs of sympathetic ganglia are present in ANS [MHCET 2015]
  - 10
  - 12
  - 22
  - 31
- If a person has lost his memory in an accident, the following part of the brain have got injured [NCERT; CBSE PMT 1992; MP PMT 1994]
  - Diencephalon
  - Medulla oblongata
  - Cerebellum
  - Cerebrum
- The hind brain consists of [CBSE PMT 1992; Kerala PMT 2009; CBSE PMT (Pre.) 2012]
  - Pons + cerebellum
  - Hypothalamus + cerebellum
  - Medulla oblongata + cerebellum
  - Medulla oblongata + cerebellum + pons
- Which of the following regions of the brain is incorrectly paired with its function [AIPMT (Cancelled) 2015]
  - Cerebellum – Language comprehension
  - Corpus callosum – communication between the left and right cerebral cortices
  - Cerebrum – calculation and contemplation
  - Medulla oblongata – homeostatic control
- Which one of the following is responsible for the control of reflex action [AFMC 1999]
  - Sensory nerves
  - Motor nerves
  - Sympathetic nervous system
  - Central nervous system
- The number of spinal nerves in man is [KCET 1999; WB JEE 2012]
  - 27 pairs
  - 31 pairs
  - 37 pairs
  - 47 pairs
- Which of the following cranial nerves are involved in the movement of eye [MH CET 2015]
  - Optic, oculomotor, abducens
  - Oculomotor, abducens, trochlear
  - Trochlear, abducens and optic
  - Abducens, optic, trochlear, oculomotor
- The smallest cranial nerve in human being is
  - Trochlear
  - Ophthalmic
  - Abducens
  - Vagus
- Post-ganglionic nerve fibres of sympathetic system are [DPMT 2006]
  - Adrenergic
  - Cholinergic
  - Both (a) and (b)
  - None of these
- The supporting and nutritive cells found in the brain are [DPMT 2006]
 

Or

 Ventricles of brain are lined by the cells called [MP PMT 1997]
  - Ependymal cells
  - Microglia
  - Astrocytes
  - Oligodendrocytes

12. Identify the origin of sympathetic nerve fibres and the location of their ganglia [CBSE PMT 1995; AIIMS 1998; BVP 2000; CPMT 2010; WB JEE 2012]

- They arise from thoraco-lumbar region of spinal cord and form ganglia just beside the vertebral column
- They arise from thoraco-cervical region of spinal cord and form ganglia just beside the vertebral column
- They arise from cranio-sacral region of spinal cord and form ganglia very close to effector organ.
- They arise from thoraco-lumbar region of spinal cord and form ganglia very close to effector organ

13. Neural stimulation in visceral organ in human being is done by [CBSE PMT 1996]

- Sympathetic and parasympathetic nerves and is under involuntary action
- Sympathetic nerves and is under voluntary action
- Sympathetic and parasympathetic nerves and is under voluntary action
- Parasympathetic nerves and is under voluntary action

14. The third ventricle of the brain is situated in the [AMU (Med.) 2010]

- Base of telencephalon
- Roof of metencephalon
- Roof of diencephalon
- Base of myelencephalon

15. The purely motor cranial nerve is [Pb. PMT 2005]

- Facial
- Vagus
- Trigeminal
- Spinal accessory

16. Foramen of Monro is an aperture between [CBSE PMT 1992]

- 2nd and 3rd ventricle
- Diocoel and metacoel
- Rhinocoel and diocoel
- 3rd and 4th ventricle

17. Hypothalamus of the brain is not involved in this function [KCET 2012]

- Sleep-wake cycle
- Osmoregulation and thirst
- Temperature control
- Accuracy of muscular movement

18. Match List I with List II and select the correct option

List I		List II	
A.	Sacral nerves	1.	1 pair
B.	Thoracic nerves	2.	8 pairs
C.	Coccygeal nerves	3.	7 pairs
D.	Cervical nerves	4.	12 pairs
E.	Lumbar nerves	5.	5 pairs

[Kerala PMT 2005, 08]

- A - 4, B - 1, C - 3, D - 2, E - 5
- A - 5, B - 3, C - 1, D - 4, E - 2
- A - 3, B - 4, C - 2, D - 5, E - 1
- A - 2, B - 5, C - 3, D - 1, E - 4
- A - 5, B - 4, C - 1, D - 2, E - 5

19. In a myelinated neuron, two adjacent myelin sheaths are separated by gaps called [Kerala PMT 2008]

- Nodes of Ranvier
- Synaptic cleft
- Schwann cells
- Synaptic knob
- Neural plate

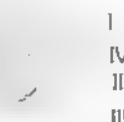
20. The branched tree like structure present in cerebellum is

Or

The tree of life is [DPMT 1993; Manipal 2005; BHU 2005]

- Arbor vitae
- Arboreal
- Archenteron
- Areole

21. The given figure is that of the human brain



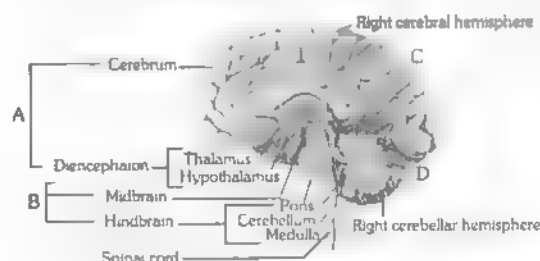
Identify the part that controls intelligence and memory is labelled [NCERT]

- IV
- III
- II
- I

22. Purely motor nerve is [BHU 1999, 2004; CPMT 2001, 02; MP PMT 2002, 06; MH CET 2003]

- Optic
- Abducens
- Ophthalmic
- Palatinus

23. See the following diagram and identify A, B, C and D [NCERT]



- A - Brainstem, B - Forebrain, C - Cerebral aqueduct, D - Corpus callosum
- A - Brainstem, B - Forebrain, C - Corpus callosum, D - Cerebral aqueduct
- A - Forebrain, B - Brainstem, C - Cerebral aqueduct, D - Corpus callosum
- A - Forebrain, B - Brainstem, C - Corpus callosum, D - Cerebral aqueduct

24. Pituicytes are under the control of [Odisha JEE 2012]

- Adenohypophysis
- Hypothalamus
- Neurohypophysis
- Both (a) and (c)

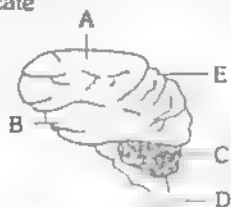
25. Which one of the following statement is correct

[CBSE PMT 2006]

- Neither hormones control neural activity nor the neurons control endocrine activity
- Endocrine glands regulate neural activity, but not vice versa
- Neurons regulate endocrine activity, but not vice versa
- Endocrine glands regulate neural activity, and nervous system regulates endocrine glands



26. The given diagram is the lateral view of the human brain, parts are indicated by alphabets. Select the answer in which these alphabets have been correctly paired with the parts which they indicate [NCERT]



- (a) A – Frontal lobe, B – Temporal lobe, C – Cerebellum, D – Medulla oblongata, E – Parietal lobe  
 (b) A – Temporal lobe, B – Parietal lobe, C – Cerebrum, D – Medulla oblongata, E – Frontal lobe  
 (c) A – Frontal lobe, B – Temporal lobe, C – Cerebrum, D – Medulla oblongata, E – Occipital lobe  
 (d) A – Temporal lobe, B – Parietal lobe, C – Cerebellum, D – Medulla oblongata, E – Frontal lobe
27. Parasympathetic ganglia are present in [AFMC 2012]  
 (a) Head and neck  
 (b) Chains of lateral ganglia  
 (c) Grey matter of thoracic and lumbar region of spinal cord  
 (d) All of these
28. Consider the given diagram and identify "A" [NCERT]



- (a) Medulla oblongata (b) Cerebellum  
 (c) Midbrain (d) Pons
29. Blood-brain barrier is formed by [BHU 2012]  
 (a) Microglial cells (b) Astrocytes  
 (c) Oligodendrocytes (d) Ependymal cells
30. Which of the following cranial nerves innervates heart, stomach and lungs [CBSE PMT 1990; MP PMT 1996; Odisha JEE 2009]

Or

- Which of the cranial nerve is mixed [WB JEE 2012]  
 (a) Vagus (b) Accessory  
 (c) Trigeminal (d) Trochlear
31. Parasympathetic nervous system increases the activity of [DPMT 1992]  
 (a) Gut, iris and urinary bladder  
 (b) Heart, adrenal and sweat gland  
 (c) Heart, pancreas and lacrimal gland  
 (d) Lacrimal gland and sweat gland
32. The nervous strip connecting both the cerebral hemispheres in the rabbit is [NCERT; MP PMT 1994, 95; RPMT 1995; CPMT 1995; MH CET 2004, 06; WB JEE 2008; Kerala PMT 2011]  
 (a) Corpus callosum (b) Corpus albicans  
 (c) Corpus stratum (d) Corpus spongiosum

33. The thermoregulatory centre is situated in

[AIIMS 1993, 2000; KCET 2000; CPMT 2001, 09; AFMC 2003]

Or

The control of blood sugar level, osmoregulation and thermoregulation are the function of [CBSE PMT 1993]

Or

The appetite and satiety centres in the brain of man are located in the region of the [CPMT 2009]

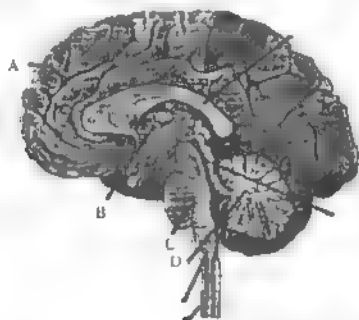
- (a) Spinal cord (b) Pituitary body  
 (c) Cerebellum (d) Hypothalamus
34. Nissl's granules are present in the ..... and are made up of ..... respectively [CBSE PMT 1997; BVP 2001; RPMT 2006]  
 (a) Muscle cells and deoxyribo nucleic acid  
 (b) Mast cells and RNA  
 (c) Osteocytes and DNA  
 (d) Neuron and RNA
35. During the course of evolution which part of the brain has shown maximum increase in size [Odisha JEE 2009]  
 (a) Mid brain (b) Fore brain  
 (c) Hind brain (d) All of the above
36. Skeletal muscles are controlled by [DUMET 2009]  
 (a) Sympathetic nerves (b) Parasympathetic nerves  
 (c) Somatic nerves (d) Autonomic nerves
37. Select the answer with correct matching of the structure, its location and function [CBSE PMT (Malwa) 2010; WB JEE 2016]
- |     | Structure       | Location  | Function  |
|-----|-----------------|---|---|
| (a) | Eustachian tube | Anterior part of internal ear                   | Equalizes air pressure on either sides of tympanic membrane |
| (b) | Cerebellum      | Mid brain                                       | Controls respiration and gastric secretions                 |
| (c) | Hypothalamus    | Fore brain                                      | Controls body temperature, urge for eating and drinking     |
| (d) | Blind spot      | Near the place where optic nerve leaves the eye | Rods and cones are present but inactive here                |
38. Integration of the visual, tactile and auditory inputs occurs in the [Kerala PMT 2012]

Or

Crura cerebrae is found in [DPMT 1993]

- (a) Peripheral nervous system  
 (b) Corpus callosum  
 (c) Limbic system  
 (d) Medulla oblongata  
 (e) Midbrain
39. Reflex action immediately involves [NCERT; BHU 2003; Kerala CET 2005]  
 (a) Spinal cord (b) Cerebellum  
 (c) Medulla oblongata (d) Optical lobe
40. Parkinsonism is related with [CBSE PMT 2001]  
 (a) Brain (b) Spinal cord  
 (c) Cranial nerves (d) Spinal nerves

41. Hearing is controlled by [MH CET 2005]  
 (a) Cerebral lobes (b) Hypothalamus  
 (c) Temporal lobe (d) Cerebellum
42. In rabbit, optic lobes are small because the eye sight is controlled by [RPMT 2001]  
 (a) Temporal lobe (b) Occipital lobe  
 (c) Frontal lobe (d) Parietal lobe
43. All spinal nerves are [RPMT 1999]  
 (a) Motor (b) Sensory  
 (c) Mixed (d) None of the above
44. The correct sequence of meninges from outer to the inner side is [DPMT 2007]  
 (a) Arachnoid – piamater – duramater  
 (b) Arachnoid – duramater – piamater  
 (c) Piamater – arachnoid – duramater  
 (d) Duramater – arachnoid – piamater
45. Body posture, equilibrium and rapid muscular activities are controlled by [AIIMS 1993; MP PMT 1995; MH CET 2006; WB JEE 2008; Odisha JEE 2012]  
**Or**  
 The part of human hind brain that is responsible for hand eye coordination is [Odisha JEE 2009]  
 (a) Cerebellum  
 (b) Thalamus  
 (c) Hippocampus  
 (d) Temporal lobe of cerebrum
46. A sagittal section of human brain is shown here. Identify at least two labels from A-D



[NEET (Karnataka) 2013]

- (a) C-Mid brain, D-Cerebellum  
 (b) A-Cerebrum, C-Pons  
 (c) B-Corpus callosum, D-Medulla  
 (d) A-Cerebral hemispheres, B-Cerebellum
47. How many cranial nerves found in the amniota [RPMT 2001]  
 (a) 6 pairs (b) 8 pairs  
 (c) 12 pairs (d) 10 pairs
48. Which of the following cranial nerves is not a motor nerve [MP PMT 2004]  
 (a) II (b) III  
 (c) IV (d) XII
49. What is found in the periphery of spinal cord [MP PMT 1996]  
 (a) Grey matter (b) Myelinated nerve  
 (c) White matter (d) Notochord

50. Which foramen is paired in mammalian brain [MP PMT 2009]  
 (a) Foramen of Luschka (b) Foramen of Magendie  
 (c) Foramen of Monro (d) Inter-ventricular foramen
51. Which one of the following pairs of structures distinguishes a nerve cell from other types of cell [CBSE PMT 2007]  
 (a) Perikaryon and dendrites  
 (b) Vacuoles and fibres  
 (c) Flagellum and medullary sheath  
 (d) Nucleus and mitochondria
52. Which one of the following cranial nerves is carrying the nerve fibres originating from the Edinger-Westphal nucleus [WB JEE 2010]  
 (a) Oculomotor (b) Trochlear  
 (c) Abducens (d) Vagus
53. Among the following characteristics, indicate the correct combinations applicable to conditional reflex  
 P. Acquired by practice or learning  
 Q. Not acquired by birth  
 R. Does not abolish by lack of practice  
 S. Participation of cerebral cortex  
 T. Originates spontaneously [WB JEE 2012]  
 (a) P, Q, R (b) P, Q, S  
 (c) P, R, T (d) Q, R, T
54. How many laminae are present in the grey matter of spinal cord [WB JEE 2010]  
 (a) Four (b) Six  
 (c) Eight (d) Ten
55. Which brain structure in rabbit is directly vision related [BHU 2003]  
 (a) Corpus albicans (b) Hippocampal lobe  
 (c) Corpus callosum (d) Corpora quadrigemina
56. A boy learns typewriting and harmonium at the same time. He finds harmonium more easy to learn. This is  
 (a) Conditioned reflex (b) Short term homeostasis  
 (c) Long term homeostasis (d) Residual learning
57. Which of the following is not related to the autonomic nervous system [WB JEE 2010]  
 (a) Peristalsis (b) Digestion  
 (c) Excretion (d) Memory and learning
58. Which is thickened to form organ of Corti [MP PMT 2009]  
 (a) Reissner's membrane (b) Basilar membrane  
 (c) Tectorial membrane (d) All of the above
59. Which is a wrong relation  
 (a) Conditioned reflex – Hodgkins  
 (b) Blood circulation – W. Harvey  
 (c) DNA double helix model – Watson and Crick  
 (d) None
60. Which of the following is the immediate covering of a nerve fibre [MP PMT 1992]  
 (a) Sarcoplasm (b) Perineurium  
 (c) Epineurium (d) Endoneurium

61. The nerves leading to the central nervous system are called [AIIMS 1993]  
(a) Efferent (b) Afferent  
(c) Motor (d) None
62. If frog's brain is crushed, even then its leg moves on pinpointing. It is called [AIIMS 2001]  
(a) Simple reflex  
(b) Conditional reflex  
(c) Neurotransmitter function  
(d) Autonomic nerve condition
63. Metacoel is the cavity in the [CBSE PMT 1993; DPMT 1993]  
(a) Cerebral hemispheres (b) Diencephalon  
(c) Cerebellum (d) Medulla oblongata
64. The innermost meninx surrounding the central nervous system in frog and man respectively are [JIPMER 1993]  
(a) Pia mater and pia mater  
(b) Arachnoid and pia mater  
(c) Pia mater and dura mater  
(d) Arachnoid and dura mater
65. Which cranial nerves has the highest number of branches [CBSE PMT 1999, 2000; CPMT 2000; AFMC 2003]  
(a) Trigeminal (b) Facial nerve  
(c) Vagus nerve (d) None of these
66. Broca's area in human brain controls [BHU 2000]  
(a) Movement of tongue (b) Breathing and hiccup  
(c) Movement of vocal cords (d) Both (a) and (c)
67. The membranes enclosing the brain and spinal cord are known as [DPMT 1993]  
(a) Meninges (b) Meningitis  
(c) Nephron (d) Axon
68. The anterior choroid plexus in the brain of man covers [AIIMS 1993]  
(a) Corpora bigemina (b) Medulla oblongata  
(c) Diencephalon (d) Mesencephalon
69. Nerve cell do not divide because they do not have [BHU 2005]  
(a) Nucleus (b) Centrosome  
(c) Golgi body (d) Mitochondria
70. Which of the following nerve innervates upper jaw of frog [RPMT 2000]  
(a) Maxillary (b) Pathetic  
(c) Palatine (d) Oculomotor
71. Which part of the human brain is largest [WB JEE 2009]  
(a) Cerebellum (b) Thalamus  
(c) Cerebrum (d) Medulla
72. The spinal cord extends from the brain through [DPMT 1993]  
Or  
The medulla oblongata of the brain passes out through [NCERT]  
(a) Foramen Magnum (b) Iler  
(c) Anterior commissure (d) Foramen of Monro
73. The nerve related with diaphragm is [MP PMT 1999]  
(a) Vagus (b) Phrenic  
(c) Trigeminal (d) Glossopharyngeal
74. Iler or cerebral aqueduct or aqueduct of Sylvius [DPMT 2004; WB JEE 2012]  
(a) In the third ventricle  
(b) In the second ventricle  
(c) Between the third and the fourth ventricles  
(d) In the lateral ventricles
75. The medulla oblongata encloses the [DPMT 1993]  
(a) Fourth ventricle (b) Second ventricle  
(c) Optic lobe (d) Otic capsule
76. Main function of cerebellum is [MP PMT 1999]  
(a) Balancing (b) To see  
(c) To hear (d) Remembering
77. Foramen of Monro is [CMC Vellore 1993; CPMT 1994]  
(a) Gap in pelvic girdle of rabbit  
(b) Foramen in the skull of frog  
(c) Space in brain of frog and rabbit  
(d) Pore in the inter-auricular septum in a mammalian heart
78. Comprehension of spoken and written words take place in the region of [WB JEE 2010]  
(a) Association area (b) Motor area  
(c) Wernicke's area (d) Broca's area
79. Four healthy people in their twenties got involved in injuries resulting in damage and death of few cells of the following. Which of the cells are least likely to be replaced by new cells [CBSE PMT 2005; RPMT 2006]  
(a) Osteocytes (b) Malpighian layer of the skin  
(c) Liver cells (d) Neurons
80. Simple two neuron reflex arc involves [MP PMT 1998]  
(a) Sensory neuron (b) Spinal cord  
(c) Effector neuron (d) All the above
81. The number of spinal nerves in rabbit is [RPMT 2000]  
(a) 27 pairs (b) 31 pairs  
(c) 37 pairs (d) 47 pairs
82. Fifth cranial nerve of frog is called [CPMT 2000; BVP 2001; BHU 2006; AFMC 2010]  
(a) Optic nerve (b) Vagus nerve  
(c) Trigeminal nerve (d) Ophthalmic nerve
83. Corpus callosum is found in the brain of [MP PMT 2000; KCET 2001]  
(a) Elephant (b) Pigeon  
(c) Crocodile (d) Frog
84. Reflex action is [CPMT 2010]  
(a) Stimulus → sensory → motor → response  
(b) Stimulus → motor → sensory → response  
(c) Reception → motor → sensory → response  
(d) Sensory → stimulus → motor → response
85. Autonomic nervous system is  
(a) Paired chain ganglia (b) Brain and spinal cord  
(c) Sense organs (d) Cerebral hemispheres
86. Cerebrospinal fluid is produced by [MP PMT 1997; Odisha JEE 2005]  
(a) Ependymal cells (b) Choroid plexus  
(c) Neuroglial cells (d) Neurons

87. Parasympathetic nerves arise from which region of the nervous system [CPMT 2010]  
(a) Thoracolumbar (b) Cervical  
(c) Craniosacral (d) Lumbar
88. In a man, abducens nerve is injured. Which one of the following functions will be affected [CBSE PMT 2005]  
(a) Movement of eye ball (b) Swallowing  
(c) Movement of the tongue (d) Movement of the neck
89. Twelve pairs of ribs and twelve pairs of cranial nerves are found in [BVP 2002; HP PMT 2005]  
(a) Fish (b) Frog  
(c) Lizard (d) Man
90. Pneumotaxic centre which can moderate the functions of the respiratory rhythm centre is present at [NCERT; Kerala PMT 2011]  
(a) Pons region of brain  
(b) Thalamus  
(c) Spinal cord  
(d) Right cerebral hemisphere  
(e) Left cerebral hemisphere
91. Secretion of which of the following is under neurosecretory nerve axons [AIIMS 1998]  
(a) Pineal (b) Adrenal cortex  
(c) Anterior pituitary (d) Posterior pituitary
92. Identify the wrong statement about frog [Kerala PMT 2012]  
(a) Parathyroid and pineal body are present  
(b) There are ten cranial nerves only  
(c) Optic lobes are situated in the mid brain  
(d) The ventricle opens into the conus arteriosus  
(e) Its an ureotelic organism
93. Which of the following has non-myelinated nerve fibres [BHU 2000]  
(a) Optic nerves (b) Cranial nerves  
(c) Spinal nerves (d) Autonomic nerves
94. How many pairs of cranial nerves in mammals are purely sensory  
(a) Five (b) Four  
(c) Three (d) Two
95. Third ventricle of rabbit's brain is called [CBSE PMT 1990]  
(a) Rhinocoel (b) Rhombocoel  
(c) Diocoel (d) None of these
96. Which of the following is a richly vascular layer with lots of blood capillaries  
(a) Duramater of brain (b) Pia mater of spinal cord  
(c) Epidermis of skin (d) Epithelial lining of trachea
97. The following cranial nerve plays an important role in regulating heart beat  
(a) IX (b) VII  
(c) X (d) VIII
98. That part of the brain which is involved in interpreting an input, storing input information and initiating a response in the light of similar past experience is [Kerala PMT 2004]  
(a) Motor area (b) Sensory area  
(c) Association area (d) Pons  
(e) Cerebellum
99. Pioneer work on conditioned reflex was done by [CPMT 1996]  
(a) Karmer (b) Pavlov  
(c) Darwin (d) Lamarck
100. Tongue is under control of [CPMT 2004; WB JEE 2011]  
(a) Trigeminal nerve  
(b) Facial nerve  
(c) Automatic nervous system  
(d) Glossopharyngeal nerve
101. Each spinal nerve in a mammal arises from the spinal cord by two roots, a dorsal and a ventral. Of these the ventral root is composed of [Pb. PMT 1999]  
(a) Somatic motor and visceral motor fibres  
(b) Somatic sensory and visceral motor fibres  
(c) Somatic motor and visceral sensory fibres  
(d) Somatic sensory and visceral sensory fibres
102. Dorsal root ganglion are [CPMT 1993]  
(a) Mixed (b) Motor  
(c) Sensory (d) None of these
103. The cytons of reflex in central nervous system and autonomic nervous system is [CPMT 1993]  
(a) Sensory (b) Mixed  
(c) Motor (d) All of these
104. Myelin sheath covers [MP PMT 2004]  
(a) Muscle fibre (b) Nerve fibre  
(c) Collagen fibre (d) Tendon
105. Reflex action in a vertebrate is an essential display exhibited by [MP PMT 1994]  
(a) Sympathetic nerve (b) Motor nerve  
(c) Sensory nerve (d) Autonomic response
106. Cerebral hemisphere is the centre of [MP PMT 1994]  
(a) Thinking (b) Will power  
(c) Reasoning (d) All of these
107. Dicondylic skull and 10 pairs of cranial nerves are found in [RPMT 1999; CPMT 2005]  
(a) Reptilia (b) Aves  
(c) Amphibia (d) All
108. Lateral ventricles are found in [MP PMT 1995]  
(a) Heart (b) Brain  
(c) Thyroid (d) Brain and heart
109. Medulla oblongata controls [RPMT 1999; CPMT 2002; MP PMT 2010, 11]  
(a) Blood pressure (b) Ventilation  
(c) Breathing (Respiration) (d) All of these
110. In after cutting through the dorsal root of a spinal nerve of a mammal, an associated receptor in the skin were stimulated, the animal would [CPMT 2005]  
(a) Still be able to feel the stimulation  
(b) Show no response  
(c) Show a normal but slow response  
(d) Respond but only at a different level of spinal cord
111. 9<sup>th</sup> pair of cranial nerve in frog is [AFMC 2005]  
(a) Hypoglossal (b) Glossopharyngeal  
(c) Vagus (d) Trigeminal

112. Which of the following part of a neuron is covered by fatty sheath  
[BHU 2004; AMU (Med.) 2005]
- Or
- The efferent process of neuron is known as [KCET 1999]
- (a) Axon (b) Cyton  
(c) Dendrite (d) Node of Ranvier
113. Injury to vagus nerve in humans is not likely to affect  
[CBSE PMT 2004]
- (a) Pancreatic secretion  
(b) Cardiac movements  
(c) Tongue movements  
(d) Gastrointestinal movements
114. Choroid plexus is a network of [KCET 2004]
- (a) Capillaries (b) Muscle fibres  
(c) Nerves (d) Lymph vessels
115. Nissl's granules are absent in [CPMT 2001; DPMT 2004]
- (a) Axon (b) Cyton  
(c) Dendron (d) Both 'a' and 'b'
116. Broca's area is situated in [WB JEE 2008]
- (a) Frontal lobe (b) Parietal lobe  
(c) Temporal lobe (d) Occipital lobe
117. Function of sympathetic nervous system is to  
[CPMT 1994; CBSE PMT 1999; RPMT 2006]
- (a) Decrease heart beat (b) Increase heart beat  
(c) Contract respiratory organ (d) Secrete saliva
118. The 3rd, 6th and 11th cranial nerves are  
[BHU 1995; AFMC 2000; Pb. PMT 2000; CPMT 2001]
- (a) Oculomotor, trigeminal, spinal  
(b) Optic, facial, spinal  
(c) Oculomotor, abducens, spinal  
(d) Trichlear, abducens, vagus
119. Which of the following connect lateral ventricle of diocoel in brain with third ventricle  
[BHU 1995; Pb. PMT 1999; MP PMT 2003; Odisha JEE 2010]
- (a) Iler (b) Foramen of Monro  
(c) Corpus striatum (d) Filum terminale
120. Sub-arachnoid space is found in [RPMT 1995]
- Or
- The arachnoid membrane covers the [MP PMT 2000]
- (a) Piamater (b) Durameter  
(c) Blastocoel (d) None of the above
121. The primary visual area is located in [KCET 2004]
- (a) Temporal lobe (b) Occipital lobe  
(c) Frontal lobe (d) Parietal lobe
122. If the sympathetic nerve to the heart is cut-off, the heart beat will  
[MP PMT 1998]
- (a) Increase (b) Decrease  
(c) Remains same (d) Stop
123. The cranial nerves which control eye-ball movement are  
[EAMCET 1998; CPMT 2000]
- (a) 4, 6 and 7 (b) 3, 4 and 6  
(c) 2, 3 and 5 (d) 5, 8 and 9
124. Conditioned reflexes are different than unconditioned reflexes in that [CPMT 1998]
- (a) Conditioned reflexes are limited to brain  
(b) Unconditioned reflexes are limited to brain  
(c) Both (a) and (b)  
(d) None of the above
125. Nodes of Ranvier are found in [MP PMT 2000; KCET 2004; BVP 2004]
- (a) Axon (b) Sperm  
(c) Muscle fibre (d) Neuron
126. Cerebrum is a part of [WB JEE 2016]
- (a) Mesencephalon (b) Metencephalon  
(c) Prosencephalon (d) Myelencephalon
127. Which one of the following cranial nerves is a parasympathetic nerve [WB JEE 2016]
- (a) Facial (b) Auditory  
(c) Abducens (d) Vagus

### Biochemical aspect of nervous physiology

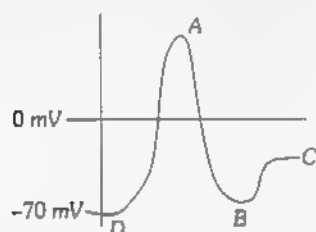
1. Reflex arc consists of [Odisha JEE 2008]
- (a) Motor nerve  
(b) Sensory nerve  
(c) Both sensory and motor nerves  
(d) None of these

2. Given below is a table comparing the effects of sympathetic and parasympathetic nervous system for four features (a-d). which one feature is correctly described [AIIMS 2008, 13]

	Feature	Sympathetic Nervous system	Parasympathetic Nervous System
(a)	Salivary gland	Stimulates secretion	Inhibits secretion
(b)	Pupil of the eye	Dilate	Constricts
(c)	Heart rate	Decreases	Increases
(d)	Intestinal peristalsis	Stimulates	Inhibits

3. Preparation of the type of stimulus depends on the [AIIMS 1992]
- (a) Strength of the nerve impulse  
(b) Specificity of connection to receptor organs  
(c) Rate of the nerve impulse  
(d) Ionic change moving in and out of the nerve
4. The following hormones are neurotransmitters [CBSE PMT 1992; Bihar CECE 2006; MP PMT 2013]
- (a) Acetylcholine and secretin  
(b) Cholecystokinin and acetylcholine  
(c) Adrenalin and acetylcholine  
(d) Cholecystokinin and adrenalin
5. Which of the following is not an effect of the sympathetic nervous system [AMU (Med.) 2010]
- (a) Dilation of pupil  
(b) Inhibition of peristalsis  
(c) Elevation of blood pressure  
(d) Stimulation for saliva secretion

6. During the transmission of nerve impulse, which of the following takes place [MP PMT 2002]
- Flux of  $\text{Na}^+$  inwards and  $\text{K}^+$  outwards
  - Flux of  $\text{K}^+$  inwards and  $\text{Na}^+$  outwards
  - Flux of  $\text{K}^+$  inwards and  $\text{Na}^+$  inwards
  - Flux of  $\text{K}^+$  outwards and  $\text{Na}^+$  outwards
7. During the propagation of a nerve impulse, the action potential results from the movement of [CBSE PMT 2008]
- $\text{K}^+$  ions from intracellular fluid to extracellular fluid
  - $\text{Na}^+$  ions from extracellular fluid to intracellular fluid
  - $\text{K}^+$  ions from extracellular fluid to intracellular fluid
  - $\text{Na}^+$  ions from intracellular fluid to extracellular fluid
8. How many pairs of cranial nerves originate from the brain of rat [Kerala PMT 2008]
- 12
  - 8
  - 9
  - 11
  - 10
9. The potential maintained across the neuron membrane during the resting state is [Kerala PMT 2008; AIIMS 2009]
- + 70 mV
  - 70 mV
  - 0.5 V
  - 30 mV
  - + 30 mV
10. The cutaneous plexus and the papillary plexus consist of [DUMET 2009]
- A network of nerves to provide dermal sensation
  - A network of arteries to provide dermal supply
  - Specialized cells for cutaneous sensations
  - Gland cells that release cutaneous secretions
- 11.



Identify the region where all  $\text{Na}^+$  channels are reactivated but closed and all  $\text{K}^+$  channels are closed [EAMCET 2009]

- D
  - C
  - B
  - A
12. Which one of the following does not act as a neurotransmitter [CBSE PMT 2006; WB JEE 2009]
- Norepinephrine
  - Cortisone/Tyrosine
  - Acetylcholine
  - Epinephrine
13. The chemical causing the transmission of nerve impulse across synapses is [KCET 1994;

BHU 1999, 2008; CBSE PMT 2000; AFMC 2001, 08; DPMT 2003; BVP 2004; CPMT 2009]

Or

The neurotransmitter which communicates between two neurons or between a neuron and a muscle is

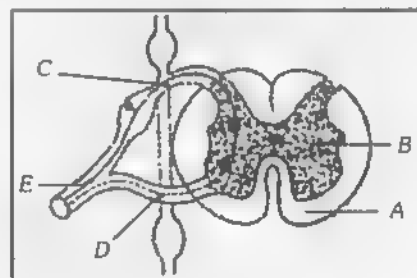
[MP PMT 1993, 95; BHU 1995; DPMT 2004; WB JEE 2016]

- Acetylcholine
- Cholinesterase
- Choline
- Acetic acid

14. The action potential of a nerve cell is
- 45 mV
  - 55 mV
  - 80 mV
  - 75 mV
15. In the following diagram showing axon terminal and synapse, A, B, C, D and E respectively represents [Kerala PMT 2010; NEET 2013; NEET (Karnataka) 2013]



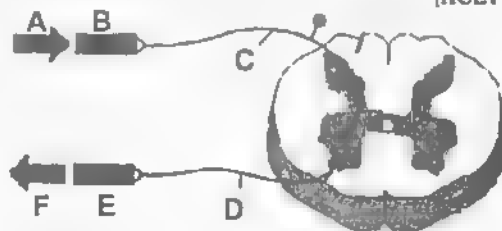
- Axon terminal, synaptic cleft, synaptic vesicles, neurotransmitters and receptors
  - Axon terminal, synaptic vesicles, synaptic cleft, receptors and neurotransmitters
  - Synaptic cleft, synaptic vesicles, axon terminal, neurotransmitters and receptors
  - Synaptic cleft, axon terminal, synaptic vesicles, neurotransmitters and receptors
  - Synaptic vesicles, axon terminal, synaptic cleft, receptors and neurotransmitters
16. In a cross section of the spinal cord A, B, C, D and E represents [Kerala PMT 2009]



- A - white matter, B - grey matter, C - dorsal root, D - ventral root, E - spinal nerve
  - A - white matter, B - grey matter, C - ventral root, D - dorsal root, E - spinal nerve
  - A - grey matter, B - white matter, C - ventral root, D - dorsal root, E - spinal nerve
  - A - grey matter, B - white matter, C - dorsal root, D - ventral root, E - spinal nerve
  - A - white matter, B - grey matter, C - spinal nerve, D - ventral root, E - dorsal root
17. The blood-brain barrier [J & K CET 2012]
- Consists of both anatomical and physiological factors
  - Regulates to some extent the passage of substances from the blood to the interstitial fluid of the brain
  - Is anatomically related to the formation of tight junctions between adjacent capillary endothelial cells
  - All of the above are correct

18. During synaptic transmission of nerve impulse, neurotransmitter (p) is released from synaptic vesicles by the action of ions (Q). Choose the correct P and Q  
[WB JEE 2012]
- P = acetylcholine, Q =  $Ca^{++}$
  - P = acetylcholine, Q =  $Na^+$
  - P = GABA, Q =  $Na^+$
  - P = cholinesterase, Q =  $Ca^{++}$
19. An investigator places an isolated neuron in a calcium free medium, gives the neuron a suprathreshold stimulus and then performs an assay to test whether neurotransmitter is released into the medium. Which of the following outcomes would you predict  
[J & K CET 2012]
- No neurotransmitter is detected since influx of calcium into the synaptic knob is required for neurotransmitter release
  - No neurotransmitter is detected since influx of calcium is required in order for the neuron to conduct an action potential
  - Neurotransmitter is detected since calcium is not required for action potential conduction and the initial stimulus was suprathreshold
  - We cannot predict the outcome without knowing whether the neuron was myelinated
20. Which option is correct for the correctly matched groups for the column I, column II and column III  
[GUJCET 2014]
- |     | Column I                   | Column II  | Column III                                       |
|-----|----------------------------|--|--|
| (a) | Resting membrane potential | i. $Na^+$ channel get open                         | e. $Na^+$ and $K^+$ pumps are responsible for it |
| (b) | Action potential           | ii. $Na^+$ channel is closed                       | f. Last for very short time                      |
| (c) | Depolarization             | iii. $Na^+$ ions are more on outer side            | g. $K^+$ ions move on outside of membrane        |
| (d) | Repolarization             | iv. $Na^+$ ions are more on inner side of membrane | h. Positive charge on inner side of membrane     |
- (a - ii - h) (b - i - g) (c - iii - e) (d - iv - f)
  - (a - iii - e) (b - iv - f) (c - i - h) (d - ii - g)
  - (a - iv - f) (b - iii - e) (c - i - e) (d - ii - h)
  - (a - iv - e) (b - iii - f) (c - ii - g) (d - i - g)
21. The release of chemical messenger from synaptic vesicles is under the influence of these ion(s)  
[AIIMS 2012]
- $Cl^-$
  - $Fe^{++}$  and  $S^{++}$
  - $Ca^{++}$
  - $Mg^{++}$  and  $Sr^{++}$
22. The potential difference between outside and inside of a nerve before excitation is known as  
[MP PMT 1996; Kerala PMT 2010]
- Resting potential
  - Action potential
  - Spike potential
  - Reaction potential
23. Depolarization of a stimulated nerve is maintained by  
[MP PMT 1996]
- $Ca^{++}$
  - $Cl^-$
  - $Mg^{++}$
  - $K^+$
24. During transmission of nerve impulse the potential inside membrane has the following type of charge [CBSE PMT 2007]
- First positive, then negative and back positive
  - First negative then positive and back negative
  - First positive then negative and remain negative
  - First negative then positive and remain positive
25. Nerve gas affects neuromuscular activity by  
[BHU 2012]
- Blocking the acetylcholine receptor sites
  - Inhibiting the release of acetylcholine
  - Inhibiting acetylcholinesterase
  - Enhancing the release of acetylcholine
26. Destruction of the anterior horn cell of the spinal cord would result in loss of  
[AIPMT 2015]
- Voluntary motor impulses
  - Commissural impulses
  - Integrating impulses
  - Sensory impulses
27. Which of the following is not a type of neuroglial cells  
[Odisha JEE 2012]
- Astrocytes
  - Oligodendrocytes
  - Microglia
  - Chondrocytes
28. Which of the following option is correct for the statement 'X' and 'Y'
- Statement 'X' – Immediately after repolarization, ionic imbalance is created on both the sides of the nerve fibre
- Statement 'Y' – During repolarization  $K^+$  ion channel open up and  $K^+$  ion moves on innerside of plasma membrane  
[GUJCET 2014]
- Statements 'X' and 'Y' are correct and 'Y' is correct for 'X'
  - Statements 'X' and 'Y' are correct and 'Y' is not correct for 'X'
  - Statement 'X' is correct and 'Y' is wrong
  - Statement 'X' is wrong and 'Y' is correct
29. Afferent nerve fibres carry impulses from  
[CBSE PMT 1992]
- Effector organs to central nervous system
  - Receptors to central nervous system
  - Central nervous system to muscles
  - Central nervous system to receptors
30. On nerve fibres to prevent leakage of an impulse layer of ..... is found  
[CPMT 1993]
- Schwann cells
  - Neurilemma
  - Axons
  - Myelin sheath
31. All sensory pathways to the cerebral cortex synapse at the  
[AMU (Med.) 2009]
- Pons
  - Hypothalamus
  - Thalamus
  - Cerebellum
32. These processes occurs during repolarization of nerve fibre
- Open  $Na^+$  channel
  - Closed  $Na^+$  channel
  - Closed  $K^+$  channel
  - Open  $K^+$  channel
- [GUJCET 2007; DPMT 2007]
- (ii) and (iv)
  - (i) and (iii)
  - (ii) and (iii)
  - (i) and (ii)

33. Which of the following is not a reflex action [BHU 2012]  
 (a) Blinking of eyes  
 (b) Salivation  
 (c) Sweating  
 (d) Withdrawal of hand on touching some hot object
34. Nerve impulse travels faster in [CPMT 1994; AFMC 2008]  
 (a) Medullated nerve (b) Non-medullated nerve  
 (c) Cranial nerve (d) Spinal nerve
35. The amount of CSF in the cranial cavity is [WB JEE 2011]  
 (a) 500 ml (b) 140 ml  
 (c) 1 litre (d) 1.5 ml
36. Synaptic vesicle is found in [DPMT 2007]  
 (a) Pre-synaptic neuron (b) Post synaptic neuron  
 (c) Synaptic left (d) None of these
37. Nerve impulse initiates with the movements of [BHU 1999; MH CET 2001; MP PMT 2003; RPMT 2006]  
 Or  
 Neuron becomes an electrically charged cell by the diffusion of [CPMT 1994; MP PMT 2006]  
 (a)  $K^+$  (b)  $Mg^+$   
 (c)  $Ca^+$  (d)  $Na^+$
38. Sodium- potassium pump is [RPMT 2001]  
 (a) A hormone (b) An enzyme  
 (c) A protein carrier (d) An organelle
39. For visual sense, the nerve impulse is generated by [RPMT 2001]  
 (a) Depolarisation  
 (b) Repolarisation  
 (c) Hyper polarisation  
 (d) Depolarisation and repolarisation
40. The enzyme required for the conduction of nerve impulses across synapse is [CBSE PMT 2001]  
 (a) Peroxidase (b) Choline acetylase  
 (c) Ascorbic acid oxidase (d) Succinic dehydrogenase
41. Unidirectional transmission of a nerve impulse through nerve fibre is due to the fact that [AIIMS 2004]  
 (a) Nerve fibre is insulated by a medullary sheath  
 (b) Sodium pump starts operating only at the cyton and then continues into the nerve fibre  
 (c) Neurotransmitters are released by dendrites and not by axon endings  
 (d) Neurotransmitters are released by the axon endings and not by dendrites
42. Cerebrospinal fluid is present [Kerala PMT 2004]  
 (a) Beneath the piamater  
 (b) Between piamater and arachnoid mater  
 (c) Between arachnoid and duramater  
 (d) In extra duramater  
 (e) Between the duramater and cranium
43. Intercellular communication in multicellular organism occurs through [BHU 2000; CPMT 2004]  
 (a) Digestive system only  
 (b) Respiratory system only  
 (c) Nervous system only  
 (d) Both nervous and endocrine system
44. Which of the following substances leads to the inhibition of central nervous system [CPMT 2004]  
 (a) Glycine (b) GABA  
 (c) Nor epinephrine (d) Both 'a' and 'b'
45. Transmission of nerve impulse, across the synapse is accomplished by [Pb. PMT 2004]  
 (a) Release of ions  
 (b) Release of neurotransmitters  
 (c) Movement of water  
 (d) Movement of  $Na^+$  and  $K^+$
46. The brain stem is made up of [KCET 2011]  
 (a) Midbrain, pons, cerebellum  
 (b) Midbrain, pons, medulla oblongata  
 (c) Diencephalon, medulla oblongata, cerebellum  
 (d) Cerebellum, cerebrum, medulla oblongata
47. Parkinson's disease (characterized by tremors and progressive rigidity of limbs) is cause by degeneration of brain neurons that are involved in movement control and make use of neurotransmitter [CBSE PMT 2005; WB JEE 2011]  
 (a) Acetylcholine (b) Nor epinephrine  
 (c) Dopamine (d) GABA
48. One of the example of the action of the autonomous nervous system is [CBSE PMT 2005]  
 (a) Knee-jerk response (b) Pupillary reflex  
 (c) Swallowing of food (d) Peristalsis of the Intestines
49. In parasympathetic nervous system which of the following is released [BHU 2005]  
 (a) Epinephrine (b) Nor epinephrine  
 (c) Serotonin (d) Acetylcholine
50. The following is the scheme showing the path of reflex arc. Identify the different labellings A, B, C, D, E, F in the reflex arc [KCET 2010]



- |     | A        | B        | C             | D             | E        | F        |
|-----|----------|----------|---------------|---------------|----------|----------|
| (a) | Stimulus | Effector | Sensory nerve | Motor nerve   | Receptor | Response |
| (b) | Stimulus | Receptor | Sensory nerve | Motor nerve   | Effector | Response |
| (c) | Stimulus | Effector | Motor nerve   | Sensory nerve | Receptor | Response |
| (d) | Stimulus | Receptor | Motor nerve   | Sensory nerve | Effector | Response |



51. Hypothalamus does not control  
[NCERT; Kerala CET 2005; WB JEE 2010]

(a) Hunger and satiety  
(b) Thermoregulation  
(c) Libido  
(d) Creative thinking and consciousness  
(e) Osmoregulation

52. You are watching a horror movie and you notice that your heart is beating fast and mouth is dry. It is because of  
[Kerala CET 2005]

(a) Fight and flight response  
(b) Autonomic nervous system  
(c) Sympathetic nervous system  
(d) Both (a) and (c)  
(e) Parasympathetic nervous system

53. Which one of the following reflex do not include innervation of brain  
[Odisha JEE 2005]

(a) Spinal reflex (b) Cranial reflex  
(c) Afferent reflex (d) Efferent reflex

54. Which of the statements about the mechanism of muscle contraction are correct

(I) Acetylcholine is released when the neural signal reaches the motor end plate  
(II) Muscle contraction is initiated by a signal sent by CNS via a sensory neuron  
(III) During muscle contraction, isotropic band gets elongated  
(IV) Repeated activation of the muscles can lead to lactic acid accumulation

[Kerala PMT 2011]

(a) I and IV are correct  
(b) I and III are correct  
(c) II and III are correct  
(d) I, II and III are correct  
(e) I and II are correct

55. In a modulated nerve fibre, the conduction of impulse is faster due to the presence of  
[Odisha JEE 2010]

(a) Pericytes  
(b) Endoneurium and epineurium  
(c) Myelin sheath and nodes of Ranvier  
(d) Nissl's granules

56. When a neuron is in resting state i.e. not conducting any impulses, the axonal membrane is [CBSE PMT (Pre.) 2011]

(a) Comparatively more permeable to  $K^+$  ions and nearly impermeable to  $Na^+$  ions  
(b) Comparatively more permeable to  $Na^+$  ions and nearly impermeable to  $K^+$  ions  
(c) Equally permeable to both  $Na^+$  and  $K^+$  ions  
(d) Impermeable to both  $Na^+$  and  $K^+$  ions

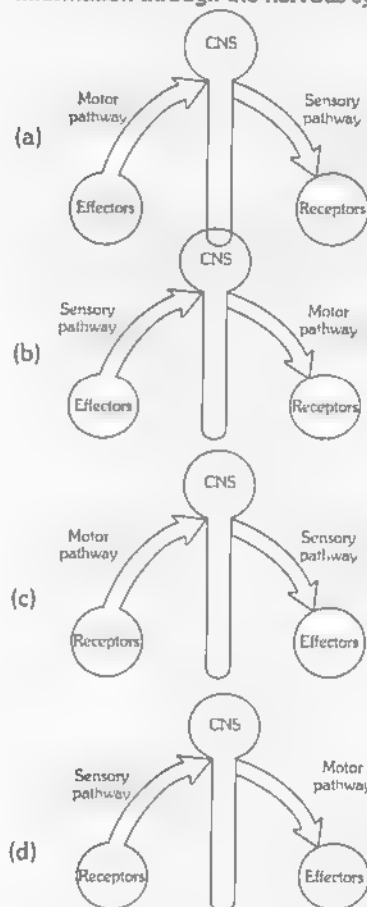
57. Which of the following statement are correct and incorrect

1. Synaptic cleft of neurons secrete adrenaline  
2. Myelinated nerve fibres are enveloped with Schwann cells, which form a myelin sheath around the axon  
3. Non-myelinated nerve fibre is enclosed by a Schwann cell that does not form a myelin sheath  
4. Spinal cord and cranial nerves are made of non-myelinated nerve fibres of the four statements

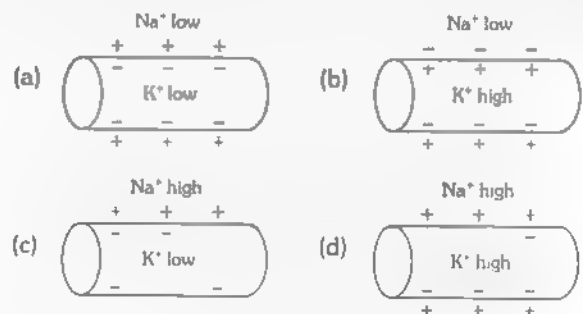
[Kerala PMT 2011]

(a) 1, 2 are correct but 3 and 4 are incorrect  
(b) 1, 2 and 3 are correct but 4 is incorrect  
(c) 3 and 4 are correct but 1 and 2 are incorrect  
(d) 1 and 4 are correct while 2 and 3 are incorrect  
(e) 2 and 3 are correct while 1 and 4 are incorrect

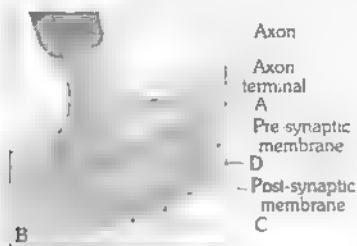
58. Choose the correct diagram which represent the flow of information through the nervous system [NCERT]



59. Which diagram shows the distribution of  $Na^+$  and  $K^+$  ions in a section of non-myelinated axon which is at resting potential [NCERT]



60. Consider the diagram of synapse

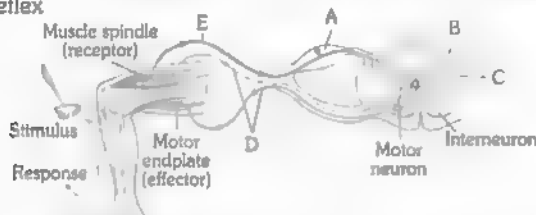


- I. The numbered label indicate the location of the receptor molecules
- II. The number points to a synaptic vesicles
- III. The number points to neurotransmitter
- IV. The number points to synaptic cleft

[NCERT]

	I	II	III	IV
(a)	C	D	A	B
(b)	C	A	D	B
(c)	B	A	C	D
(d)	C	A	B	D

61. The given diagram represent reflex action shows knee jerk reflex



In which of the following option correct words for all the 5 blanks (A to E) are illustrate

[NCERT]

	A	B	C	D	E
(a)	Ventral root ganglion	White matter	Gray matter	Efferent pathway	Afferent pathway
(b)	Dorsal root ganglion	Gray matter	White matter	Efferent pathway	Afferent pathway
(c)	Dorsal root ganglion	White matter	Gray matter	Efferent pathway	Afferent pathway
(d)	Dorsal root ganglion	White matter	Gray matter	Afferent pathway	Efferent pathway

62. Stimulation of a muscle fibre by a motor neuron occurs at

[CBSE PMT 2014]

- (a) The myofibril
  - (b) The sarcoplasmic reticulum
  - (c) The neuromuscular junction
  - (d) The transverse tubules
63. Select the correct combination of statements for the neurotransmitters
- [WB JEE 2016]
- (a) Acetylcholine is inactivated mainly by presynaptic reuptake
  - (b) Tyrosine is essential for the formation of dopamine
  - (c) Adrenaline is formed by methylation of the noradrenaline
  - (d) Serotonin is synthesized from phenylalanine
64. Receptor sites for neurotransmitters are presents on
- [NEET 2017]
- (a) Membranes of synaptic vesicles
  - (b) Pre-synaptic membrane
  - (c) Tips of axons
  - (d) Post-synaptic membrane

65. Myelin sheath is produced by

[NEET 2017]

Or

Myelin of the nerve fibres of the central nervous system is produced and maintained by

[AMU (Med.) 2009]

- (a) Schwann cell and Oligodendrocytes
- (b) Astrocytes and Schwann cells
- (c) Oligodendrocytes and Osteoclasts
- (d) Osteoclasts and Astrocytes

### Different types of Receptors

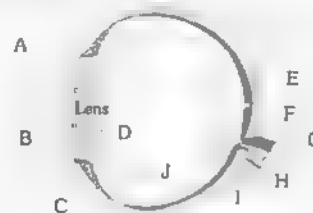
1. The pacinian corpuscle present in the skin is for
- [DPMT 1993; MH CET 2006; AMU (Med.) 2010]
- (a) Pain
  - (b) Pressure
  - (c) Movement
  - (d) Temperature
2. Colour blindness results from
- [MP PMT 1996; AFMC 1997; WB JEE 2010]
- (a) Absence of rods
  - (b) Absence of cones
  - (c) Absence of eyelids
  - (d) Inverted retina
3. In fishes the lateral line receptors are neuromast organs. These are
- [AFMC 2006]
- (a) Olfactoreceptors
  - (b) Gustatoreceptors
  - (c) Rheoreceptors
  - (d) Chemoreceptors
4. Jacobson's organ is concerned with
- [CPMT 1994; Kerala PMT 2004; MH CET 2006; WB JEE 2010]
- (a) Smell
  - (b) Burrowing
  - (c) Touch
  - (d) Sight
5. Jacobson's organ in man
- [MP PMT 1995; AFMC 2001]
- (a) Functions as smelling organs
  - (b) Functions as gustatory organ
  - (c) Is a vestigeal organ
  - (d) Functions as pain sensory organ
6. Sonar system is found only in
- [MP PMT 2000]
- (a) Bats
  - (b) Whales
  - (c) Bats and whales
  - (d) Otter
7. Osphradium of *Pila globosa* is
- [APMEE 1999; CBSE PMT 2000; BHU 2000, 01; CPMT 2001; DPMT 2004]
- (a) Photoreceptor
  - (b) Chemoreceptor
  - (c) Thermoreceptor
  - (d) Tangoreceptor
8. Meissner's corpuscles are located in
- [CPMT 1992, 2002; AIIMS 1993]
- (a) Pancreas and secrete trypsinogen
  - (b) Adrenal and secrete epinephrin
  - (c) Spleen and destroy worn out erythrocytes
  - (d) Skin and perceive gentle pressure
9. Vibrissae are associated with the function of
- [JIPMER 1993]
- (a) Thermoregulation
  - (b) Gustation
  - (c) Tactile perception
  - (d) Reproduction
10. Sensation of stomach pain is due to
- [AIIMS 1998]
- (a) Interoceptors
  - (b) Exteroceptors
  - (c) Proprioceptors
  - (d) Teloreceptors
11. The sweet and acidic tastes are better detected by
- (a) Tip of the tongue
  - (b) Base of the tongue
  - (c) Middle of the tongue
  - (d) Lateral sides of the tongue
12. Proprioceptors are those, which give the sense of
- [MP PMT 2001; CBSE PMT 2001]
- (a) Chemicals
  - (b) Temperature
  - (c) Taste
  - (d) Changes in the internal environment of the body

13. Sea gulls excrete excess of NaCl from [BHU 2005]  
 (a) Liver (b) Lungs  
 (c) Nasal cavity (d) Kidney
14. Animals which have well developed echolocation system like that of bats [KCET 1994; Kerala CET 2002; CPMT 2003; Kerala PMT 2004; J & K CET 2008]  
 (a) Wild cats (b) Beavers  
 (c) Primates (d) Whales and dolphins  
 (e) Hedgehogs
15. The receptors found in the muscles, tendons and joints are [MP PMT 1996, 2002]  
 (a) Teloreceptors (b) Proprioceptors  
 (c) Interoceptors (d) None of these

### Eye

1. Which part of the eye controls the amount of light entering in it [MP PMT 1992; CPMT 1993; DPMT 1993]  
 Or  
 The black pigment in the eye which reduces the internal reflection is located in [AIIMS 1998]  
 (a) Cornea (b) Ciliary body  
 (c) Iris (d) Suspensory ligament
2. Which of the following prevents internal reflection of light within the eye [RPMT 2005]  
 Or  
 Coloured (Pigmented) layer of eye is [RPMT 1995]  
 (a) Cornea (b) Choroid  
 (c) Sclera (d) Conjunctiva
3. In the chemistry of vision in mammals, the photosensitive substance is called [CBSE PMT 1997]  
 Or  
 The visual pigment in rods of vertebrate eye which is responsible for detection of light is  
 Or  
 It is present in rods and useful in night vision [GUJCET 2007]  
 (a) Sclerotin (b) Retinol  
 (c) Rhodopsin (d) Melanin
4. In mammalian eye, the 'fovea' is the centre of the visual field, where [BHU 2003; AIPMT 2015; WB JEE 2016]  
 (a) The optic nerve leaves the eye  
 (b) Only rods are present  
 (c) More rods than cones are found  
 (d) High density of cones occur, but has no rods
5. Which one of the following is correct pairing of a body part and the kind of muscle tissue that moves it [CBSE PMT 2009]  
 (a) Heart wall – involuntary unstriated muscle  
 (b) Biceps of upper arm – Smooth muscle fibres upper arm  
 (c) Abdominal wall – Smooth muscle  
 (d) Iris – Involuntary smooth muscle
6. In the following abnormalities of the eye which one is a serious condition that leads to blindness [Kerala CET 2003]  
 (a) Presbyopia (b) Myopia  
 (c) Hypermetropia (d) Glaucoma

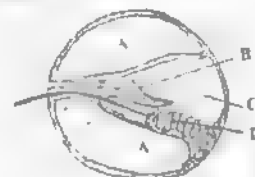
7. Study the following figure



- I. Carries nerve signals to the brain  
 II. Regulates the size of the pupil to let more or less light into the eye  
 III. Changes the shape of the lens  
 IV. Photoreceptors are highly concentrated at this center of focus

The correct match of the above functions with parts of the eye indicated by letters is [NCERT]

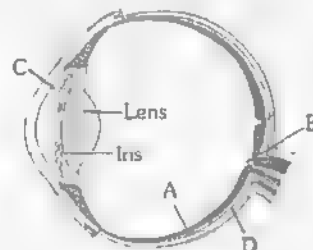
- (a) I - G, II - D, III - C, IV - E (b) I - A, II - C, III - E, IV - G  
 (c) I - J, II - G, III - F, IV - C (d) I - B, II - D, III - F, IV - H
8. Given below is a diagrammatic cross section of a single loop of human cochlea



[CBSE PMT 2008; AIIMS 2012]

- Which one of the following options correctly represents the names of three different parts
- (a) D : Sensory hair cells, A : Endolymph, B : Tectorial membrane  
 (b) A : Perilymph, B : Tectorial membrane, C : Endolymph  
 (c) B : Tectorial membrane, C : Perilymph, D : Secretory cells  
 (d) C : Endolymph, D : Sensory hair cells, A : Serum
9. In the blind spot where the optic nerves leave the eye [NCERT; AFMC 2006]  
 (a) Rods and cones are absent  
 (b) Only cones are present  
 (c) Only rods are present  
 (d) Special neurons are present
10. Dark adaptation in human eye involves [AMU (Med.) 2012]  
 (a) Conversion of 11 *cis* retinene to *trans* retinene  
 (b) Conversion of *trans* retinene into 11 *cis* retinene  
 (c) Decomposition of rhodopsin into retinene  
 (d) Decomposition of rhodopsin to scotopsin
11. Cavity of vitreous humour in the eyes are situated [AIIMS 1993]  
 (a) Behind the lens  
 (b) Infront of the lens  
 (c) Behind the retina  
 (d) Between the retina and sclerotic

12. The rods and cones of the eye retinal layer are modified  
[AFMC 2005; MP PMT 2009; Odisha JEE 2012]  
(a) Hair (b) Unipolar neurons  
(c) Bipolar neurons (d) Multipolar neurons
13. The purplish red pigment rhodopsin contained in the rods type of photoreceptor cells of the human eye, is a derivative of  
[NCERT; CBSE PMT (Pre.) 2011]  
(a) Vitamin A (b) Vitamin B<sub>1</sub>  
(c) Vitamin C (d) Vitamin D
14. Iodopsin is a light sensitive (photosensitive) pigment and is present in the  
[CPMT 1992, 93; Bihar CECE 2006; AFMC 2010; DUMET 2010]  
(a) Rods (b) Cones  
(c) Neuroglia (d) Bipolar cells
15. Retina is most sensitive at [AFMC 1997; MHCET 2002]  
(a) Optic disc (b) Periphery  
(c) Macula lutea (d) Fovea centralis
16. Which function will be lost due to damage of occipital lobe  
[MH CET 2007; WB JEE 2011]  
(a) Hearing (b) Speech  
(c) Vision (d) Memory
17. UV radiation from sun causes which of the following disorder of eyes  
[BHU 2004]  
(a) Cataract (b) Glaucoma  
(c) Dilation pupil (d) Some defect of retina
18. Which one of the following is the correct difference between Rod Cells and Cone Cells of our retina [CBSE PMT 2008]
- |                              | Rod Cells                             | Cone Cells  |
|------------------------------|---------------------------------------|---|
| (a) Overall function         | Vision in poor light                  | Colour vision and detailed vision in bright light |
| (b) Distribution             | More concentrated in centre of retina | Evenly distributed all over retina                |
| (c) Visual acuity            | High                                  | Low   |
| (d) Visual pigment contained | Iodopsin                              | Rhodopsin   |
19. Cornea transplant in humans is almost never rejected. Because [CBSE PMT 1996, 2008]  
(a) It is composed of enucleated cells  
(b) It is a non-living layer  
(c) Its cells are least penetrable by bacteria  
(d) It has no blood supply
20. The function of Iris in the eyes of frog is to [BHU 1999]  
(a) Refraction of light rays  
(b) Alter the size of the pupil  
(c) Move the nictitating membrane  
(d) Move the lens forward and backward
21. Fovea in the eye is a central pit in the yellowish pigmented spot called [Kerala PMT 2008]  
(a) Blind spot (b) Retina  
(c) Cornea (d) Macula lutea  
(e) Choroid
22. Iris of an eye is an extension of [NCERT]  
(a) Cornea (b) Sclerotic  
(c) Retina (d) Both choroid and retina
23. Acute vision is found in  
(a) Vulture (b) Frog  
(c) Shark (d) Bat
24. The optic lobes in humans are represented by the corpora [NCERT; AMU (Med.) 2010, 12]  
(a) Bigemina (b) Arenacea  
(c) Striata (d) Quadrigemina
25. Sensory neurons of retina of eye are [Odisha JEE 2009]  
(a) Rods and cones  
(b) Maculae and cristae  
(c) Pacinian and Ruffini's corpuscles  
(d) All of these
26. The decoding and interpretation of visual information is carried out by which part of the brain [Kerala PMT 2006]  
(a) Cerebellum (b) Frontal lobe  
(c) Parietal lobe (d) Temporal lobe  
(e) Occipital lobe
27. Parts A, B, C and D of the human eye are shown in the diagram. Select the option which gives correct identification along with its functions/ characteristics



- (a) D – Choroid – its anterior part forms ciliary body  
(b) A – Retina – contains photo receptors-rods and cones  
(c) B – Blind spot – has only a few rods and cones  
(d) C – Aqueous chamber reflects the light which does not pass through the lens [NEET 2013]
28. Protein found in eye lens is [DPMT 2007]  
(a) Crystallin (b) Collagen  
(c) Opsin (d) Rhodopsin
29. The size of pupil is controlled by the [NCERT; DUMET 2009]  
(a) Ciliary muscles (b) Suspensory ligaments  
(c) Cornea (d) Iris muscles
30. Match the following
- | Column I        | Column II                               |
|-----------------|---|
| (A) Fovea       | (1) Provides opening for entry of light |
| (B) Iris        | (2) Transduces RGB light                |
| (C) Pupil       | (3) Transmits information to CNS        |
| (D) Lens        | (4) Controls amount of light entering   |
| (E) Optic nerve | (5) Focuses light on the retina         |
- [NCERT; Kerala PMT 2009]  
(a) (A) — (4), (B) — (1), (C) — (5), (D) — (2), (E) — (3)  
(b) (A) — (5), (B) — (1), (C) — (4), (D) — (3), (E) — (2)  
(c) (A) — (3), (B) — (1), (C) — (4), (D) — (5), (E) — (2)  
(d) (A) — (1), (B) — (2), (C) — (3), (D) — (4), (E) — (5)  
(e) (A) — (2), (B) — (4), (C) — (1), (D) — (5), (E) — (3)

31. The muscles surrounding the pupil of rabbit's eye are [CPMT 2004]  
(a) Unstriated and involuntary (b) Striated and voluntary  
(c) Unstriated and voluntary (d) Striated and involuntary
32. In human beings the total visual field and the stereoscopic visual field respectively is [AMU (Med.) 2009]  
(a) 180° and 140° (b) 140° and 26°  
(c) 180° and 26° (d) 140° and 52°
33. The innermost layer of the human eye is [Kerala PMT 2010]  
(a) Choroid (b) Cornea  
(c) Sclera (d) Retina  
(e) Lens
34. The iris of eye is [RPMT 1999]  
(a) Photosensitive (b) Chemoreceptor  
(c) Calororeceptor (d) All
35. The unit of photoreception, in a compound eye of cockroach and other insects, is [Pb. PMT 1999]  
(a) Ctenidium (b) Osphradium  
(c) Ommatidium (d) Rhabdome
36. In the myopia eye defect, the rays of light [CBSE PMT 2000; AIIMS 2003]  
(a) Do not enter the eye at all  
(b) Come to a focus at back of retina  
(c) Come to a focus in front of the retina  
(d) Come to a focus in between retina & iris
37. Only rods are present in the eyes of one of the following animals [MP PMT 2001]  
(a) Pigeon (b) Squirrel  
(c) Fowl (d) Owl
38. Vitreous humour is seen in [CBSE PMT 1993]  
(a) Ear (b) Eye  
(c) Brain (d) Bone marrow
39. The space between the lens and the cornea of the human eye is [AIIMS 1993]  
(a) Vitreous chamber (b) Aqueous chamber  
(c) Retina (d) Iris
40. Glaucoma is an eye disease arising from [JIPMER 1993, 2002]  
(a) Increased pressure of fluid in eye ball  
(b) Elongation of eye ball  
(c) Shortening of eye ball  
(d) Irregularity in the surface of cornea
41. The movement of eye ball is brought about by the [DPMT 1993]  
(a) Adductor muscle (b) Rectus muscle  
(c) Biceps (d) Peroneus
42. The hollow of the eye is divided into aqueous chamber and vitreous chamber by [DPMT 1993; MP PMT 2007]  
(a) Optic nerve (b) Retina  
(c) Lens (d) Iris
43. The central opening of iris is called as [CBSE PMT 1993]  
(a) Pupil (b) Cornea  
(c) Lens (d) Fovea centralis
44. The human eye is sensitive only to light having wave length ranging from [JIPMER 2002]  
(a) 80 to 280 nanometres (b) 380 to 760 nanometres  
(c) 780 to 870 nanometres (d) 880 to 980 nanometres
45. The number of occipital condyles in man is/are [Kerala PMT 2010]  
(a) One (b) Two  
(c) Three (d) Four  
(e) Five
46. The posterior part of the retina, which is just opposite to the lens is [AIIMS 2009]  
(a) Cornea (b) Yellow spot  
(c) Area centralis (d) Both (b) and (c)
47. In man, the image formation occur on retina for most bright vision it should form on [RPMT 2001]  
(a) At the place of entry of optic nerve  
(b) Blind spot  
(c) Yellow spot  
(d) At the junction of ciliary body and lens
48. Which of the following have "ommatidia" as unit of eye [RPMT 2001]  
(a) *Pheretima* (b) House fly  
(c) *Pila* (d) Sepia
49. Sensitive (pigmented) layer of eye is [NCERT; MP PMT 2006; Odisha JEE 2010]  
(a) Sclerotic (b) Retina  
(c) Cornea (d) None of these
50. The cornea and lens of the mammalian eyes are both  
(a) Richly supplied by nerves  
(b) Richly supplied by blood vessels  
(c) Transparent and they diverge the light rays to form an image on retina  
(d) Transparent and they contribute in the formation of image on retina
51. Lens of eye retina is developed from [CPMT 1998]  
(a) Ectoderm (b) Mesoderm  
(c) Endoderm (d) Ecto-mesoderm
52. Choroid is  
(a) Middle layer of ear (b) Innermost layer of eye  
(c) Innermost layer of ear (d) Middle layer of eye
53. As compared to rods the cones are ..... times less sensitive  
(a) 100 (b) 200  
(c) 300 (d) 400
54. A 22 years student goes to his ophthalmologist. He has problem in reading books because he is not able to contract his [CPMT 2009]  
(a) Suspensory ligament (b) Pupil  
(c) Iris (d) Ciliary muscles
55. The lens and cornea is not having blood supply. So the nutrients are supplied by [Kerala CET 2003]  
(a) Retina (b) Blind spot  
(c) Vitreous body (d) Aqueous humour
56. Photosensitive compound in human eye is made up of [NEET (Phase-I) 2016]  
(a) Guanosine and Retinol (b) Opsin and Retinal  
(c) Opsin and Retinol (d) Transducin and Retinene

57. Choose the correct statement [NEET (Phase-II) 2016]  
 (a) Receptors do not produce graded potentials  
 (b) Nociceptors respond to changes in pressure  
 (c) Meissner's corpuscles are thermoreceptors  
 (d) Photoreceptors in the human eye are depolarized during darkness and become hyperpolarized in response to the light stimulus
58. Which cell in the retina recognize colour [WB JEE 2016]  
 (a) Rod cells (b) Cone cells  
 (c) Both Rod and Cone cells (d) Epithelial cells
- 
- Ear**
- 
1. Hearing in rabbit is better than frog. One reason for this is that rabbit has [MP PMT 1992]  
 (a) Three semicircular canal  
 (b) Vibratile tympanic membrane  
 (c) Movable pinna  
 (d) Both fenestra ovalis and eustachian tubes
2. Scala vestibuli is connected with [NCERT; MP PMT 1992]  
 (a) Fenestra rotundus (b) Fenestra ovalis  
 (c) Scala tympani (d) Scala media
3. Identify the correct sequence of organs/regions in the organization of human ear as an auditory mechanoreceptor organ [NCERT; Kerala PMT 2007]  
 (a) Pinna – Cochlea – Tympanic membrane – Auditory canal – Malleus – Stapes – Incus – Auditory nerve  
 (b) Pinna – Tympanic membrane – auditory canal – Incus – Malleus – Stapes – Cochlea – Auditory nerve  
 (c) Pinna – Malleus – Incus – Stapes – Auditory canal – Tympanic membrane – Cochlea – Auditory nerve  
 (d) Pinna – Tympanic membrane – Auditory canal – Cochlea – Malleus – Incus – Stapes – Auditory nerve  
 (e) Pinna – Auditory canal – Tympanic membrane – Malleus – Incus – Stapes – Cochlea – Auditory nerve
4. Statolith is an organ which helps in [DPMT 1993]  
 (a) Vision (b) Equilibrium  
 (c) Tactile stimulation (d) Chemical stimulation
5. Acoustic spots in frog is present in [CPMT 2002; RPMT 2005]  
 (a) Ossious labyrinth (b) Carotid  
 (c) Membranous labyrinth (d) All of these
6. The tympanic cavity is connected with the pharynx by  
 (a) Columella (b) Ear ossicles  
 (c) Eustachian tube (d) Fallopian tubes
7. Our ear can hear the frequency of sound waves [Kerala CET 2003]  
 (a) 20 to 20,000 cycles/sec  
 (b) 1000 to 2000 cycles/sec  
 (c) 5000 to 7000 cycles/sec  
 (d) 5000 to 10,000 cycles/sec
8. The perception of sound by a mammal involves the stimulation of the mechano receptors located in the internal ear [CPMT 1992]  
 (a) On the organ of corti  
 (b) On the Reissner's membrane  
 (c) In the sacculus  
 (d) In the semicircular canal
9. The true sense of equilibrium in mammals are situated in the [RPMT 2001]  
 (a) Malleus (b) Utriculus  
 (c) Eustachian tubes (d) Semicircular canal
10. The bony labyrinth is filled with [NCERT; DPMT 1993]  
 (a) Endolymph (b) Synovial fluid  
 (c) Perilymph (d) Humour
11. Which part is not included in Cochlear duct [GUJCET 2015]  
 (a) Reissner's membrane (b) Macula of Utricle  
 (c) Scala Media (d) Tectorial membrane
12. The kind of tissue that forms the supportive structure in our pinna (external sears) is also found in [CBSE PMT 2009]  
 (a) Vertebrae (b) Nails  
 (c) Ear ossicles (d) Tip of the nose
13. High frequency sound waves vibrate the basilar membrane [AMU (Med.) 2009; WB JEE 2016]  
 (a) Near the oval window  
 (b) Near the helicotrema  
 (c) In the middle of cochlea  
 (d) From oval window to helicotrema
14. Eustachian tube connects [NCERT; CPMT 2009]  
 (a) Pharynx with middle ear  
 (b) Middle ear with internal ear  
 (c) Middle ear with external ear  
 (d) External ear with internal ear
15. Utriculus is the part of internal ear or membranous labyrinth which forms  
 (a) Lower chamber and is concerned with maintenance of equilibrium  
 (b) Lower chamber and is concerned with transmission of sound waves  
 (c) Upper chamber and is concerned with maintenance of equilibrium  
 (d) Upper chamber and is concerned with perception
16. Internal ear is filled with [AFMC 2005]  
 (a) Perilymph (b) Endolymph  
 (c) Lymph (d) Both (a) and (b)
17. Vibrations of fenestra ovalis are transmitted to  
 (a) Perilymph of scala vestibuli  
 (b) Perilymph of scala tympani  
 (c) Endolymph of scala media  
 (d) Endolymph of scala vestibuli
18. Canal joining middle ear with buccal cavity is [MP PMT 2001]  
 (a) Inguinal canal (b) Eustachian canal  
 (c) Haversian canal (d) Aquaduct of Sylvius
19. Malleus is present in the [CBSE PMT 1993]  
 (a) Inner ear (b) Outer ear  
 (c) Middle ear (d) Eye

20. Which part of the human ear plays no role in hearing as such but is otherwise very much required

[NCERT; CBSE PMT (Pre.) 2012]

Or

Which of the following is balancing organ

[DPMT 2007; Kerala PMT 2010; AIPMT (Cancelled) 2015]

- (a) Eustachian tube (b) Organ of Corti  
(c) Vestibular apparatus (d) Ear ossicles
21. The sense of equilibrium by ear is the function of  
(a) Sensory cells of the organ of Corti  
(b) Sensory crista of the ampulla  
(c) Tectorial membrane of cochlea  
(d) Basilar membrane of cochlea
22. Consider the given sectional view of Cochlea. Identify A, B, C, D and E  
[NCERT; MH CET 2015]



- (a) A - Scala vestibuli, B - Scala media, C - Scala tympani, D - Reissner's membrane, E - Basilar membrane  
(b) A - Scala tympani, B - Scala media, C - Scala vestibuli, D - Basilar membrane, E - Reissner's membrane  
(c) A - Scala media, B - Scala vestibuli, C - Scala tympani, D - Basilar membrane, E - Reissner's membrane  
(d) A - Scala vestibuli, B - Scala media, C - Scala tympani, D - Basilar membrane, E - Reissner's membrane
23. Columella auris is a modified [CBSE PMT 1992]  
(a) Articular (b) Sphenoid  
(c) Hyomandibular (d) Quadrate
24. A person going upto 10,000 feet high in a hot air balloon may develop severe pain in the ear due to  
(a) Blocked eustachian tube  
(b) Rupture of fenestra rotunda  
(c) Endolymph getting into semicircular canals  
(d) Fear of great height
25. Which of the following nerve supplies organ of Corti [RPMT 2002]  
(a) Auditory (b) Olfactory  
(c) Trochlear (d) Vagus
26. The vibrations of the tympanic membrane are amplified approximately.....times in the oval window  
[AMU (Med.) 2010]  
(a) 5 (b) 20  
(c) 40 (d) 55
27. The opening in the nasopharynx that permits air pressure on both sides of tympanic membrane of the ear to be kept equal is [AIIMS 1992; CPMT 1992; JIPMER 2002]  
(a) Oval window (b) Tube of cochlea  
(c) Auditory nerve (d) Eustachian tube

28. In mammalian ear, a membranous structure which separate the scala vestibuli and scala media is

[NCERT; MP PMT 2003]

- (a) Basilar membrane (b) Reissner's membrane  
(c) Autolith membrane (d) Tectorial membrane

29. The organ of Corti in rabbit is concerned with the sense of [CPMT 1993; RPMT 2001; AFMC 2010]

Or

Cochlea of mammalian internal ear is concerned with

- (a) Smell (b) Hearing  
(c) Taste (d) Equilibrium

30. Otoconium is found in [CBSE PMT 2000]

- (a) Perilymph (b) Haemolymph  
(c) Synovial fluid (d) Otolithic membrane

31. Ear drum is known as [MP PMT 1999]

- (a) Tympanic membrane (b) Tensor tympani  
(c) Scala tympani (d) Scala vestibuli

32. In the ear of man, the perilymph passes from middle to inner ear through [NCERT; CPMT 1999; JIPMER 2001]

- (a) Foramen ovale (b) Fenestra ovalis  
(c) Fenestra rotundus (d) Tympanic membrane

33. Organ of Corti is found in

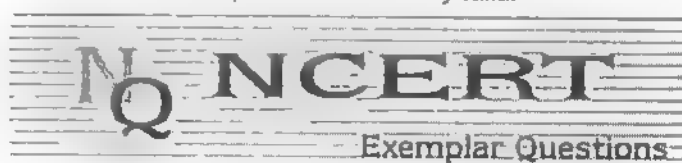
[CPMT 1998; MHCET 2000; BVP 2001]

- (a) Internal ear (b) External ear  
(c) Both (a) and (b) (d) None of these

34. See the following diagram. Identify 1 to 8 [NCERT]



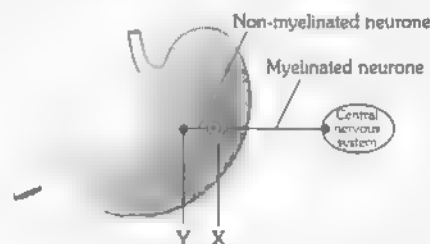
- (a) 1 - Temporal bone, 2 - Malleus, 3 - Incus, 4 - Cochlea, 5 - Stapes, 6 - Eustachian tube, 7 - Tympanic membrane, 8 - External auditory canal  
(b) 1 - Temporal bone, 2 - Incus, 3 - Malleus, 4 - Stapes, 5 - Cochlea, 6 - Eustachian tube, 7 - Tympanic membrane, 8 - External auditory canal  
(c) 1 - Tympanic membrane, 2 - Malleus, 3 - Incus, 4 - Stapes, 5 - Cochlea, 6 - Eustachian tube, 7 - Temporal bone, 8 - External auditory canal  
(d) 1 - Temporal bone, 2 - Malleus, 3 - Incus, 4 - Stapes, 5 - Cochlea, 6 - Eustachian tube, 7 - Tympanic membrane, 8 - External auditory canal



1. Chemicals which are released at the synaptic junction are called [NCERT]

- (a) Hormones (b) Neurotransmitter  
(c) Cerebrospinal fluid (d) Lymph

2. Potential difference across resting membrane is negatively charged. This is due to differential distribution of the following ions [NCERT]  
(a)  $\text{Na}^+$  and  $\text{K}^+$  ions (b)  $\text{CO}_3^{++}$  and  $\text{Cl}^-$  ions  
(c)  $\text{Ca}^{++}$  and  $\text{Mg}^{++}$  ions (d)  $\text{Ca}^{+4}$  and  $\text{Cl}^-$  ions
3. Resting membrane potential is maintained by [NCERT]  
(a) Hormones (b) Neurotransmitters  
(c) Ion pumps (d) None of the above
4. The function of our visceral organs is controlled by [NCERT; WB JEE 2016]  
(a) Sympathetic and somatic neural system  
(b) Sympathetic and para sympathetic neural system  
(c) Central and somatic nervous system  
(d) None of the above
5. Which of the following is not involved in Knee-jerk reflex [NCERT]  
(a) Muscle spindle (b) Motor neuron  
(c) Brain (d) Inter neurons
6. An area in the brain which is associated with strong emotions is [NCERT]  
(a) Cerebral cortex (b) Cerebellum  
(c) Limbic system (d) Medulla
7. Human eyeball consists of three layers and it encloses [NCERT]  
(a) Lens, iris, optic nerve  
(b) Lens, aqueous humor and vitreous humour  
(c) Cornea, lens, iris  
(d) Cornea, lens, optic nerve
8. Wax gland present in the ear canal is called [NCERT]  
(a) Sweat gland  
(b) Prostate gland  
(c) Cowper's gland  
(d) Sebaceous gland/ceruminous gland
9. The part of internal ear responsible for hearing is [NCERT]  
(a) Cochlea (b) Semicircular canal  
(c) Utriculus (d) Sacculus
10. The organ of corti is a structure present in [NCERT]  
(a) External ear (b) Middle ear  
(c) Semi circular canal (d) Cochlea
3. How do parasympathetic neural signals affect the working of the heart [MP PMT 1996; CBSE PMT 2014]  
(a) Both heart rate and cardiac output increase  
(b) Heart rate decreases but cardiac output increases  
(c) Reduce both heart rate and cardiac output  
(d) Heart rate is increased without affecting the cardiac output
4. The accumulation of protein called amyloid  $\beta$  peptide in human brain causes [Kerala PMT 2006]  
(a) Addison's disease (b) Huntington's disease  
(c) Alzheimer's disease (d) Motor-neuron disease  
(e) Parkinson's disease
5. The reflex arc which is made of two neurons is known as [WB JEE 2011]  
(a) Monosynaptic reflex arc (b) Disynaptic reflex arc  
(c) Polysynaptic reflex arc (d) Asynaptic reflex arc
6. Match the entries in column I with those in column II and choose the correct combination from the options given
- | Column I          | Column II     |
|-------------------|---------------|
| A. Diencephalon   | 1. Cerebellum |
| B. Telencephalon  | 2. Medulla    |
| C. Myelencephalon | 3. Amygdala   |
| D. Metencephalon  | 4. Thalamus   |
- [Kerala PMT 2006]  
(a) A-4, B-3, C-1, D-2  
(b) A-3, B-4, C-1, D-2  
(c) A-4, B-3, C-2, D-1  
(d) A-1, B-2, C-3, D-4  
(e) A-4, B-1, C-2, D-3
7. Suppose a person wears convex glasses for proper vision. Where you think the image of the object is formed in his eyes when he is not using the glasses  
(a) On the blind spot (b) On the yellow spot  
(c) Behind the retina (d) In front of the retina
8. The given diagram shows the parasympathetic innervation of smooth muscle and glands of the stomach



Select the right option in which the chemical transmitters are released at the synapses X and Y are correctly identified

[NCERT]

- (a) X - noradrenaline, Y - calcium ions  
(b) X - acetylcholine; Y - noradrenaline  
(c) X - acetylcholine; Y - calcium ions  
(d) X - acetylcholine; Y - acetylcholine

## Critical Thinking

### Objective Questions

1. Which part of the brain is involved in loss of control when a person drinks alcohol [Kerala CET 2003]  
(a) Cerebellum (b) Cerebrum  
(c) Medulla oblongata (d) Pons varoli
2. In reflex action the reflex arc is formed by [NCERT]  
(a) Brain - spinal cord - muscles  
(b) Receptor - spinal cord - muscles  
(c) Muscles - receptor - brain  
(d) Muscles - spinal cord - muscles



9. The ventricles of the brain are filled with [DPMT 1993]  
 (a) Cerebro-spinal fluid (b) Lymph  
 (c) Blood (d) Amniotic fluid
10. In Myasthenia gravis acetylcholine [AMU (Med.) 2010]  
 (a) Receptors on motor end plate are reduced  
 (b) Secretion from nerve terminals is reduced  
 (c) Esterase activity is inhibited  
 (d) Secretion from nerve terminals is enhanced
11. Vagus (Pneumogastric) nerve is [CBSE PMT 1992; BVP 1997, 2001; KCET 1998; Wardha 2005; WB JEE 2016]  
 (a) Spinal nerve (b) Sympathetic nerve  
 (c) X-cranial nerve (d) Parasympathetic nerve
12. Which one is the function of parasympathetic nervous system in mammals [CBSE PMT 1990]  
 (a) Acceleration of heart beat  
 (b) Constriction of pupil  
 (c) Stimulation of sweat glands  
 (d) Contraction of arrector pili muscles
13. Which cranial nerve carries in excitation from the ear [MP PMT 1994]  
 Or  
 The cranial nerve which brings impulses from the internal ear is [MP PMT 2013]  
 (a) Optic (b) Auditory  
 (c) Olfactory (d) Trigeminal
14. Which is a characteristic of a graded potential [AMU (Med.) 2009]  
 (a) The amplitude is always the same  
 (b) The duration varies  
 (c) Always followed by a refractory period  
 (d) Is an all or none response
15. The centre for sense of smell in brain is [MP PMT 1999, 2003; AFMC 2003, 05; MH CET 2004, 07]  
 (a) Cerebellum (b) Cerebrum  
 (c) Olfactory lobes (d) Midbrain
16. Brain depends on blood for the supply of [CPMT 1999; RPMT 1999; JIPMER 2001]  
 (a) Oxygen and ATP (b) Oxygen and electrolytes  
 (c) Oxygen and glucose (d) ATP and glucose
17. The sound waves produce the vibrations in the endolymph, which in turn affects one of the following to produce the stimuli for hearing  
 (a) Basilar membrane (b) Tectorial membrane  
 (c) Reissner's membrane (d) Cochlear duct
18. The venom of cobra affects the [JIPMER 1994; BVP 2000; AFMC 2009; MP PMT 2013]  
 (a) Digestive system (b) Circulatory system  
 (c) Nervous system (d) Respiratory system
19. The jumping of action potential from node to node (of Ranvier) in a fibre is called [CPMT 1992]  
 (a) All or none principle (b) Threshold stimulus  
 (c) Nodal conduction (d) Saltatory conduction

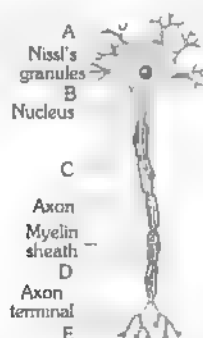
20. The given diagram is that of human brain



Which functions is performed by the part labelled III in the given diagram [NCERT]

- (a) Maintaining posture  
 (b) Controlling learning  
 (c) Regulation of heartbeat  
 (d) Regulation of body temperature
21. Molecules that bear charged groups of opposite polarity are known as [DUMET 2010]  
 (a) Zwitterions (b) Cations  
 (c) Anions (d) Negative ions
22. Synaptic fatigue is due to  
 (a) Exhaustion of neurotransmitter  
 (b) Release of more acetylcholine  
 (c) Release of more adrenaline  
 (d) None of these
23. A touch on the right hand stimulates neurons in [Odisha JEE 2005]  
 (a) Left somatic sensory area  
 (b) Right somatic sensory area  
 (c) Both (a) and (b)  
 (d) None of these
24. Read the following statements and choose the correct option  
 A. Blood cells secrete fibres of structural proteins called collagen or elastin  
 B. Neuroglial cells protect and support the nephrons  
 C. Osteocytes are present in spaces called lacunae  
 D. Striated muscle fibres are bundled together in a parallel fashion  
 E. Biceps are involuntary and striated [Kerala PMT 2012]  
 (a) C and D alone are wrong  
 (b) B and D alone are wrong  
 (c) A and C alone are wrong  
 (d) B and C alone are wrong  
 (e) A, B, and E alone are wrong
25. Small lesions on spinal tissue, slip disc in spinal column and micro cancer like tumour are detected by [AMU (Med.) 2005; Kerala PMT 2009]  
 (a) Magnetic resonance imaging method  
 (b) Sonography method  
 (c) Positron Emission Tomography method  
 (d) X-ray Radiography method

26. Manifestation of increase in the blood pressure of a person is called [J & K CET 2005]  
(a) Hypertension (b) Atherosclerosis  
(c) Arteriosclerosis (d) None of these
27. Mouth becomes watery when we look on the delicious food is due to [J & K CET 2005]  
(a) Olfactory response (b) Hormonal response  
(c) Neural response (d) Optic response
28. An action potential in the nerve fibre is produced when positive and negative charges on the outside and the inside of the axon membrane are reversed, because [AIIMS 2007]  
(a) More potassium ions enter the axon as compared to sodium ions leaving it  
(b) More sodium ions enter the axon as compared to potassium ions leaving it  
(c) All potassium ions leave the axon  
(d) All sodium ions enter the axon
29. Taste buds detect the substance only when the substance is  
(a) Solid (b) Semisolid  
(c) Semiliquid (d) Liquid
30. 'Adaptation' of eyes in dark is due to [BHU 2005]  
(a) Depletion of vision pigment in rod  
(b) Depletion of vision pigment in cones  
(c) Repletion of vision pigment in rods  
(d) Repletion of vision pigment in cones
31. In mammals, sound wave receptors are [MP PMT 1998]  
(a) Ears (b) Eyes  
(c) Skin (d) Hair
32. Organs of Ruffini are receptors of [BHU 1995; AMU (Med.) 2006; MP PMT 2007]  
(a) Heat (b) Cold  
(c) Pressure (d) Touch
33. The given figure show the structure of neuron. Identify A, B, C, D and E [NCERT]



	A	B	C	D	E
(a)	Dendrites	Cyton or cell body	Nerve cell	Node of Ranvier	Synaptic knob
(b)	Dendrites	Nerve cell	Schwann cell	Node of Ranvier	Synaptic knob
(c)	Dendrites	Cyton or cell body	Schwann cell	Node of Ranvier	Synaptic knob
(d)	Nerve fibre	Cyton or cell body	Schwann cell	Node of Ranvier	Synaptic knob

34. When the intensity of light is low during night, the light is detected by [MP PMT 1996, 2002, 11]  
(a) Rods (b) Cones  
(c) Lens (d) Both rods and cones
35. Fovea centralis of retina perceives [MP PMT 1992]  
(a) Diffused light (b) Dim light  
(c) Coloured light (d) Coloured and dim light
36. Eye is said to be near-sighted when a [MP PMT 1992]  
(a) Near object is focussed in front of the retina  
(b) Distant object is focussed in front of retina  
(c) Near object is focussed behind the retina  
(d) Distant object is focussed behind the retina
37. If an organism has more rods it will [BVP 2004]  
(a) Active during day  
(b) Possess colour vision  
(c) Active during night  
(d) Both 'a' and 'c' are possible
38. The pupil becomes bigger to allow more light during dark by the  
(a) Contraction of radial muscles of the iris  
(b) Relaxation of radial muscles of the iris  
(c) Contraction of circular muscles of the iris  
(d) Contraction of suspensory ligaments
39. The part of an eye which acts like a diaphragm of a photographic camera is  
(a) Pupil (b) Iris  
(c) Lens (d) Cornea
40. The defective condition of accommodation of the eye in which distant objects are seen distinctly but near objects are indistinct is [AFMC 1994]  
(a) Astigmatism (b) Presbyopia  
(c) Myopia (d) Hypermetropia
41. The point in eye of mammals from which optic nerves and blood vessels leaves the eye ball is [NCERT; AFMC 2004]  
(a) Yellow spot (b) Blind spot  
(c) Pars optica (d) None of these
42. Fishes have very poor sense organs for [BHU 2000]  
(a) Detecting odours  
(b) Light perception  
(c) Sound perception  
(d) Detecting vibrations in water
43. The eyes of cat, cow, buffalo and some nocturnal animals shine in night. It is due to the presence of tapetum lucidum between the choroid and retina. This shining is due to the presence of a pigment made of  
(a) Cytocine (b) Uracil  
(c) Guanine (d) Thiamine
44. In which direction cristae of rabbit ear helps in maintaining balance [RPMT 2006]  
(a) Circular position of longitudinal axis of semi circular canals  
(b) Transverse position of longitudinal axis of semi circular canals  
(c) Parallel to longitudinal axis of semi circular canals  
(d) All of the above

45. In cataract [RPMT 2001; JIPMER 2002]  
 (a) Due to ageing or some infection eye lens becomes opaque  
 (b) Elasticity of eye lens is lost  
 (c) There is irregular curvature of lens  
 (d) Eye ball becomes shorter
46. How many eye muscles are present which control all types of eye movement  
 (a) 3 (b) 4  
 (c) 5 (d) 6
47. Bowman's glands are located in the [MP PMT 1998; CBSE PMT 2007]  
 (a) Proximal end of uriniferous tubules  
 (b) Anterior pituitary  
 (c) Female reproductive system of cockroach  
 (d) Olfactory epithelium of our nose
48. What is the correct sequence of the parts of the eye that the light rays cross in reaching the retina [CMC Vellore 1993]  
 (a) Pupil → cornea → aqueous humour → lens → vitreous humour  
 (b) Lens → cornea → aqueous humour → vitreous humour → pupil  
 (c) Aqueous humour → vitreous humour → cornea → pupil → lens  
 (d) Cornea → aqueous humour → pupil → lens → vitreous humour
49. The cornea is a very important component of the human eye. The main function of the cornea is to [AIIMS 2010]  
 (a) Bend the light before it reaches the lens  
 (b) Provide structural support to the eye  
 (c) Contain a concentrated amount of cone cells in the correct orientation  
 (d) Change the shape of the lens to enable the image to be focused on the retina

## R Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

- (a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion  
 (b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion  
 (c) If the assertion is true but the reason is false  
 (d) If both the assertion and reason are false  
 (e) If the assertion is false but reason is true

1. Assertion : The imbalance in concentration of  $\text{Na}^+$ ,  $\text{K}^+$  and proteins generates resting potential  
 Reason : To maintain the unequal distribution of  $\text{Na}^+$  &  $\text{K}^+$ , the neurons use electrical energy. [AIIMS 2002, 09]

2. Assertion : Rabies is acute infectious disease of warm blooded mammals characterized by involvement of central nervous system resulting in paralysis and finally death.  
 Reason : This is caused due to neurotropic filterable bacteria in saliva of rabid animals. [AIIMS 2000]
3. Assertion : Transmission of the nerve impulse across a synapse is accomplished by neurotransmitters.  
 Reason : Transmission across a synapse usually requires neurotransmitters because there is small space i.e. synaptic cleft, that separates one neuron from another [AIIMS 1999]
4. Assertion : Medulla oblongata causes reflex actions like vomiting, coughing and sneezing.  
 Reason : It has many nerve cells which control autonomic reflexes. [AIIMS 1994]
5. Assertion : Anterior lobe of pituitary is attached to hypothalamus by a vein.  
 Reason : This attachment is done through a portal vein. [AIIMS 1993]
6. Assertion : After hearing a sound, nerve impulse passes from neurons to the brain.  
 Reason : The neurons which pass nerve impulses from the body organ to the brain is called afferent neuron.
7. Assertion : Cerebrospinal fluid is present throughout the central nervous system.  
 Reason : CSF has no such function.
8. Assertion : All motor neurons are efferent neurons.  
 Reason : Motor neurons conduct nerve impulses from the spinal cord to the brain.
9. Assertion : Some areas of the brain and spinal cord look white.  
 Reason : This is because cell bodies of neurons are situated in those areas.
10. Assertion : In man, only peripheral nervous system is present.  
 Reason : The peripheral nervous system includes nerves coursing between the central nervous system and different parts of the body.
11. Assertion : Spinal cord has a column of both grey and white matter  
 Reason : Grey matter forms the central spinal canal
12. Assertion : Vitamin A deficiency produces night blindness  
 Reason : Photosensitive pigment rhodopsin is synthesised from vitamin A.
13. Assertion : Tongue is a gustatoreceptor.  
 Reason : Receptors for gustatory sensations are located in the taste bud. [AIIMS 2000]

14. Assertion : Circular smooth muscles of iris contract when bright light falls on the eye.  
Reason : Pupil gets constricted by the contraction of circular smooth muscles of iris.
15. Assertion : Sparrows possess poor night vision.  
Reason : Sparrows eyes are made up of ommatidia.
16. Assertion : The eye is said to have power of accommodation.  
Reason : Ciliary muscles alters the shape of the lens for near or far vision during accommodation.
17. Assertion : Nerve fibre can become excited through touch, smell, pressure and chemical changes and there is a change in polarity.  
Reason : It is called active potential [GUJCET 2015]

## Answers

### Development of central nervous system in human

1	b	2	c	3	a	4	a	5	b
6	d	7	a	8	d	9	b		

### Part of nervous system

1	c	2	c	3	d	4	d	5	a
6	d	7	b	8	b	9	a	10	a
11	a	12	a	13	a	14	c	15	d
16	a	17	d	18	e	19	a	20	a
21	d	22	b	23	d	24	b	25	d
26	a	27	a	28	b	29	b	30	a
31	a	32	a	33	d	34	d	35	b
36	c	37	c	38	a	39	a	40	a
41	c	42	b	43	c	44	d	45	a
46	b	47	c	48	a	49	c	50	a
51	a	52	a	53	b	54	d	55	d
56	a	57	d	58	b	59	a	60	d
61	b	62	a	63	d	64	a	65	c
66	d	67	a	68	c	69	b	70	a
71	c	72	a	73	b	74	c	75	a
76	a	77	c	78	c	79	d	80	d
81	c	82	c	83	a	84	a	85	a
86	b	87	c	88	a	89	d	90	a
91	c	92	b	93	d	94	c	95	c
96	b	97	c	98	c	99	b	100	d
101	a	102	c	103	c	104	b	105	d
106	d	107	c	108	b	109	d	110	b
111	b	112	a	113	c	114	a	115	a
116	a	117	b	118	c	119	b	120	a
121	b	122	c	123	b	124	a	125	a
126	c	127	ad						

### Biochemical aspect of nervous physiology

1	c	2	b	3	d	4	c	5	d
6	a	7	b	8	a	9	b	10	a
11	b	12	b	13	a	14	a	15	b
16	a	17	d	18	a	19	a	20	b
21	c	22	a	23	d	24	b	25	c
26	a	27	d	28	c	29	b	30	d
31	a	32	a	33	c	34	a	35	b
36	a	37	d	38	c	39	d	40	b
41	d	42	b	43	d	44	d	45	b
46	b	47	c	48	d	49	d	50	b
51	d	52	d	53	a	54	a	55	c
56	a	57	e	58	d	59	d	60	d
61	c	62	c	63	abd	64	d	65	a

### Different types of Receptors

1	b	2	b	3	c	4	a	5	c
6	c	7	b	8	d	9	c	10	a
11	a	12	d	13	c	14	d	15	b

### Eye

1	c	2	b	3	c	4	d	5	d
6	d	7	a	8	b	9	a	10	b
11	a	12	c	13	a	14	b	15	c
16	c	17	a	18	a	19	d	20	b
21	d	22	d	23	a	24	d	25	a
26	e	27	b	28	a	29	d	30	e
31	a	32	a	33	d	34	a	35	c
36	c	37	d	38	b	39	b	40	a
41	b	42	c	43	a	44	b	45	b
46	d	47	c	48	b	49	b	50	d
51	a	52	d	53	c	54	d	55	d
56	b	57	d	58	b				

### Ear

1	c	2	c	3	a	4	b	5	c
6	c	7	a	8	a	9	d	10	c
11	b	12	d	13	a	14	a	15	c
16	d	17	a	18	b	19	c	20	c
21	b	22	d	23	c	24	b	25	a
26	b	27	d	28	b	29	b	30	d
31	a	32	b	33	a	34	d		

## NCERT Exemplar Questions

1	b	2	a	3	c	4	b	5	c
6	c	7	b	8	d	9	a	10	c

## Critical Thinking Questions

1	a	2	b	3	c	4	c	5	a
6	c	7	c	8	d	9	a	10	a
11	cd	12	b	13	b	14	c	15	c
16	c	17	b	18	c	19	d	20	c
21	a	22	a	23	a	24	e	25	a
26	a	27	c	28	b	29	d	30	c
31	a	32	a	33	c	34	a	35	c
36	b	37	c	38	a	39	b	40	d
41	b	42	c	43	c	44	b	45	a
46	d	47	d	48	d	49	a		

## Assertion and Reason

1	c	2	c	3	a	4	a	5	b
6	b	7	c	8	c	9	c	10	e
11	b	12	a	13	a	14	b	15	c
16	b	17	b						

# AS

## Answers and Solutions

### Development of central nervous system in human

2. (c) Corpus callosum is a thick whitish band of semicircular nerve fibres interconnecting two cerebral hemispheres (found only in mammals).
4. (a) Largest cell in the body is neuron. Certain neurons may almost equal the length of body itself.
5. (b) Optic nerve is sensory, therefore it originates from retina and is distributed in mid-brain.
7. (a) Sympathetic nervous system increases defence system of body against adverse conditions. It is active in stress condition. Such as pain fear and anger.
8. (d) Autonomic nervous system regulates and coordinates involuntary activities like heart beating, homeostasis, body temperature, breathing, gut peristalsis and secretion of glands.

### Parts of nervous system

1. (c) VIII, the auditory cranial nerve.
3. (d) A mammal, from whose brain cerebrum is removed loses all responses that depend upon consciousness and memory.

4. (d) Hind brain has two distinct part (i) metencephalon (medulla oblongata) (ii) myelencephalon (cerebellum), transverse band of white matter called pons varoli.
5. (a) Cerebellum is responsible for co-ordination of body movements.
6. (d) Reflex action is an immediate involuntary response to a stimulus with out the intervention of brain, controlled by spinal cord of central nervous system.
7. (b) Man has 31 pairs of spinal nerves while rabbit has 37 pairs.
8. (b) III, IV and VI cranial nerves.
9. (a) The smallest cranial nerve is trochlear in human beings.
10. (a) The post-ganglionic nerve fibres of sympathetic nervous system are adrenergic i.e., they release the neurotransmitter nor-adrenaline at their termination. The sympathetic nerves stimulate the adrenal glands to secrete adrenaline.

The post-ganglionic para-sympathetic fibres are cholinergic i.e., they release a chemical substance acetyl choline, a neurotransmitter, at their endings for the transmission of nerve impulses.

11. (a) Ependymal cells are columnar cells that have ciliated surface. They support the central nervous system and also nutritive in function.
12. (a) Sympathetic nerves are composed of efferent fibres derived from the thoracic and lumbar regions of the spinal cord.
15. (d) Accessory nerves arise from the side of medulla oblongata and supply to the muscles of the pharynx, larynx neck and shoulder. They are motor nerves.
16. (a) Between paracoel and diocoel.
20. (a) Arbor vitae is a branched tree like structure composed of white matter in cerebellum.. It is also presumed to be the seat of soul
22. (b) Abducens is motor nerve which arise from the ventral surface of medulla oblongata these nerve helps in rotation of eye balls. The optic are sensory nerve. Ophthalmic and palatinus are mixed nerve.
31. (a) Parasympathetic nervous system stimulates the peristaltic movement of digestive tract, contracts the wall of urinary bladder and reduces the diameter of the pupil by contracting the iris.
32. (a) It coordinates the activity of both the cerebral hemispheres.
33. (d) Hypothalamus contains higher nerve centres for temperature regulation, hunger, thirst and emotional reactions.
37. (c) Hypothalamus is the floor of diencephalon which is the part of fore brain. It has thermoregulatory centre, hunger and thirst centre.
38. (e) Crura cerebrae are thickened ventral portions of the mid-brain of a vertebrate consisting of nervous tracts linking the thalamencephalon with the hind-brain

39. (a) Reflexes are classified as the spinal reflexes and the cranial reflexes. The former are so called because their basic neural path leads through spinal nerves and spinal cord. Reflexes at the spinal level have the purpose of removing the animal from harmful stimuli.
40. (a) Parkinson's disease or paralysis agitans is a defect of brain.
41. (c) The primary acoustic centre is in the temporal lobe of cerebral hemispheres.
42. (b) Occipital lobe is the centre for sight as the greater part of the visual area lies in it.
43. (c) All spinal nerves are sensory and motor both (mixed)
44. (d) Central nervous system comprises brain and spinal cord both are surrounded by the three protective membranes these are duramater, arachnoid mater – piamater.
45. (a) Cerebellum primary functions is to maintain posture, orientation and equilibrium of body by co-ordinating and regulating tone and contraction of voluntary muscles, mainly according to the commands of cerebellum.
48. (a) The motor cranial nerves are III, IV, VI, XI and XII.
49. (c) The thick wall of spinal cord consists of an inner zone of grey matter and a peripheral zone of white matter.
52. (a) Oculomotor nerve has oculomotor nucleus and Edinger-Westphal nucleus.
55. (d) The upper or superior surface of the "mid brain" has two pairs of rounded protrusions collectively called the corpora quadrigemina one pair is called superior colliculi and the other pair is called inferior colliculi. In frog, corpora quadrigemina are the optic lobes. The superior colliculi are concerned with sense of sight. However inferior colliculi are concerned with hearing.
56. (a) Reflexes developed by training and learning are called conditioned or acquired reflexes for example after proper learning, we can perform dancing, cycling, swimming, singing, playing etc. simply by reflexes.
57. (d) Autonomic nervous system controls involuntary functions of the visceral organs.
59. (a) Conditional reflexes were first demonstrated by the Russian scientist, Pavlov in dogs
61. (b) Nerve that connect only receptor organs to the CNS are purely sensory or afferent nerve because these contain only sensory nerve fibres.
62. (a) Reflex is the spontaneous automatic mechanical response to a stimulus without animals' will.
63. (d) Ventricles I and II of cerebral hemispheres are called as paracoels or lateral ventricles. Ventricle III is known as diocoel. Ventricle IV is the metacoel.
65. (c) Vagus nerve has five branches –
  - (i) Superior laryngeal nerve
  - (ii) Recurrent laryngeal nerve
  - (iii) Cardiac nerve
  - (iv) Pneumogastric nerve
  - (v) Depresser nerve
66. (d) Broca's area is the speech centre which controls the movement of lips, tongue, larynx, pharynx etc
67. (a) Brain and spinal cord are surrounded by three meninges – duramater and piamater, arachnoid in mammals.
68. (c) It is found at the roof of diencephalon. The anterior part of the diencephalon is vascular and folded to form the anterior choroid plexus.
69. (b) Nerve cell are highly specialized cell which have no power of division because they do not have centrosome
70. (a) This is also sensory. It brings sensory impulse from the skin of upper lip upper jaw, nasal mucosa and lower eyelids.
72. (a) The medulla oblongata passes out through the foramen magnum and continues into spinal cord, which is contained in the neural canal of vertebral column.
75. (a) The cavity of the hind brain, called fourth ventricle, is rhomboidal and limited to the anterior part of medulla oblongata.
77. (c) The cavities (= lateral ventricles or paracoels) of the cerebral hemispheres remain separate in frontal lobes. In temporal lobes these join together and communicate behind, by a common foramen of monro, with the diocoel (3<sup>rd</sup> ventricle) cavity of diencephalon.
78. (c) Wernicke's area is responsible for understanding speech.
79. (d) Neurons the specialized all of nervous system. In nervous system has no power of regeneration.
80. (d) Reflex arc is the basic functional unit of nervous system. The entire impulse circuit of a reflex response.  
receptors → CNS → effector
81. (c) Cervical – 8 pairs, thoracic – 12 pairs, lumbar – 7 pairs, sacral – 4 pairs, caudal – 6 pairs i.e. total 37 pairs.
82. (c) Trigeminal nerve is the fifth cranial nerve of frog. It arises from the antero-lateral sides of medulla oblongata.
83. (a) A band of white nerve fibres, the corpus callosum connects the two cerebral hemispheres together in mammalian brain.
85. (a) In which sympathetic nerve fibres are included.
88. (a) Abducens is the sixth number of motor cranial nerve which regulate the movement of eye ball.

89. (d) In human beings, the 12 pairs of cranial nerves and 31 pairs of spinal nerves and 12 pairs of Ribs are present.
94. (c) I, II and VIII i.e. olfactory, optic and auditory.
95. (c) Ventricle III is known as diocoel is a small cavity of diencephalon.
97. (c) X-cranial nerve controls the visceral sensation, and visceral movements (peristalsis, sound production, respiratory movements, heart beat)
99. (b) Ivan Pavlov of Russia (1906), on the basis of experiments with dogs showed that conditioned reflex affects behaviour.
101. (a) The nerve fibres of ventral root carry motor impulses away from the spinal cord.
102. (c) Sensory nerve fibres are located in the dorsal root ganglion.
104. (b) The medullary sheath, or myelin sheath is continuous around the nerve fibres in the CNS but in the nerve fibres of PNS it is absent.
105. (d) Autonomic response obviously occur very fast we do not even feel the stimulus. Thus reflex reaction protect the body against injurious effects of sudden stimuli.
106. (d) Cerebrum (cerebral hemisphere) is centre of thinking, will power, reasoning and memory, experience and learning knowledge and articulate speech.
108. (b) Lateral ventricles are cavities of cerebrum.
109. (d) Medulla oblongata contains centre for the autonomic reflex control of respiration, heart beat and these centre are called vital centres because damage to them is usually total.
112. (a) Myelinated or medullated nerve fibre (Axon) is surrounded by inner thick medullary sheath of fatty material called myelin
114. (a) The thin roof of III ventricle (diocoel) is called epithalamus. The anterior part of epithalamus contains a highly coiled bunch of blood capillaries called anterior Choroid plexus. The dorsal surface of metacoel also contains highly coiled bunch of blood capillaries called post choroid plexus.
115. (a) Axon is a single long process of uniform thickness. It contains neurofibrils and neurotubules but lacks Nissl's granules, Golgi complex, ribosomes etc.
116. (a) Broca's area is part of frontal lobe of cerebrum is related with speech.
117. (b) Sympathetic nervous system increases the (i) rate and force of heart beat, (ii) constricts most blood vessels, (iii) raises the arterial blood pressure, (iv) dilates the pupil, (v) slows down peristaltic movements, (vi) and relaxes the urinary bladder.
118. (c) 3<sup>rd</sup>, 6<sup>th</sup>, 11<sup>th</sup> cranial nerve are oculomotor, abducens and spinal accessory respectively. All of these are motor nerve.
119. (b) Foramen of Monro is the space in the brain of frog and rabbit which joins lateral ventricle of diocoel to the III ventricle of brain.
120. (a) Subarachnoid space is found between arachnoid mater and pia mater. It contains CSF. It is absent in frog but present in mammals.
122. (c) In myogenic heart, heart beat is continuous even after the nerve supply is cut.
123. (b) The cranial nerve III, IV and VI are motor nerve and control eye ball movement known as III oculomotor IV trochlear and VI Abducens nerve.
124. (a) Unconditioned reflexes are inborn, inherited and species specific and stable and controlled by spinal cord.  
Conditioned reflexes are acquired by learning and experiences and controlled by cerebral cortex of brain.
125. (a) Nodes of Ranvier are uncovered part of an axon.
126. (c) Cerebrum is the part of fore-brain, which develops from embryonic prosencephalon.
127. (ad) Parasympathetic nervous system includes four cranial nerves – III [Oculomotor] VII [Facial], IX [Glossopharyngeal] and X [Vagus]

### Biochemical aspect of nervous physiology

4. (c) Nerve impulses are transmitted from axon to dendron with the help of acetylcholine and adrenaline called neurotransmitters, produced by the secretory vesicles of the synaptic knob.
6. (a) The movement of  $\text{Na}^+$  into the axoplasm leads to the depolarization of nerve.
13. (a) Arrival of an impulse at the synaptic knob causes the acetylcholine to be discharged into synaptic cleft.
20. (b) (a) During resting membrane potential,  $\text{Na}^+$  ions are more on the outer side of membrane due to  $\text{Na}^+ - \text{K}^+$  ion pumps; (b) Action potential lasts only for very short time and  $\text{Na}^+$  ions are more on the inner side of membrane; (c) During depolarization,  $\text{Na}^+$  ion channels open leading to influx of  $\text{Na}^+$  developing positive charge on inner side of plasma membrane; (d) During repolarization,  $\text{Na}^+$  ion channel gets closed and  $\text{K}^+$  ion channels open leading to efflux of  $\text{K}^+$  moving it outside of membrane.
23. (d) Efflux of  $\text{K}^+$  causes repolarization. Therefore it is the movement of  $\text{K}^+$  that maintains the depolarized state.

26. (a) In poliomyelitis, anterior horn cells of spinal cord are destroyed which result in loss of motor activities of limbs.
28. (c) At the end of repolarization, a difference in concentration of positive ions on two sides of plasma membrane is generated leading to ionic imbalance. During repolarization,  $K^+$  ion channels open up and  $K^+$  ions move out of the plasma membrane.
29. (b) Nerve impulse carry through afferent nerve fibres from receptors to central nervous system.
30. (d) It is a strong insulating layer which prevents almost all flow of ions through the axonic surface and thus prevent the leakage of impulse.
34. (a) On medullated nerve fibres speed of nerve impulse is about 20 times faster than on non-medullated nerve fibres.
36. (a) In a synapse, the transmitting cell is called the presynaptic cell and the gap in between is called a synaptic cleft. Synaptic vesicles are found in presynaptic neuron. They contain neurotransmitters which on stimulation are released into the synaptic cleft and then these chemicals combine with the receptors on the postsynaptic neuron causing depolarization.
37. (d)  $Na^+$  enters in the axoplasm leading to depolarization of the nerve
39. (d) Nerve impulse is a self propagating wave of depolarization and repolarization.
42. (b) Sub-arachnoid space found between the arachnoid membrane and pia-mater, which is filled with cerebrospinal fluid.
43. (d) Animals have two system of co-ordination i.e., nervous system and endocrine system. Neurones are the basic structural and functional units of the nervous system which spread through out the organism forming a complex communication network. Endocrine system release hormone for intercellular communication.
44. (d) Gamma amino butyric acid (GABA) and glycine are inhibitory transmitters. An inhibitory transmitter is one that is released by an inhibitory neuron. It can inhibit impulse at synapse
45. (b) Transmission of nerve impulse, across a synapse is accomplished by neurotransmitters because of synapse. It separates one neuron from other.
47. (c) Parkinson's disease is characterised by tremors and progressive rigidity of limbs caused by a degeneration of brain neurons and a neurotransmitter called dopamine.
48. (d) Autonomic nervous system regulates and coordinates involuntary activities like heart beating, homeostasis, body temperature, breathing, gut peristalsis and secretion of glands.
49. (d) The post ganglionic parasympathetic fibres release a chemical substance acetylcholine.
51. (d) Hypothalamus contains higher nerve centre for temperature regulation, hunger, thirst and osmoregulation.
56. (a) When a neuron is in resting state i.e., not conducting any impulse, the axonal membrane is comparatively more permeable to  $K^+$  ions and nearly impermeable to  $Na^+$  ions.
62. (c) Neuromuscular junction is the junction between motor neuron and muscle fibre.
63. (abd) Tyrosine amino acid is required for synthesis of dopamine. Adrenaline is formed by methylation of nor-adrenaline using Phenylethanolamine N-methyltransferase.
65. (a) In CNS, myelin sheath is formed by oligodendrocytes, while in PNS, it is formed by Schwann cells

### Different types of Receptors

- (b) Pacinian corpuscles are tactile receptors occur in deeper layer of skin in neck, arms, nipples, external genital, palms and soles. These receive stimulus of strong pressure and vibrations of sustained contacts.
- (b) Rod is a kind of light-sensitive nerve cell present in vertebrate retina. Rods do not discriminate fine details or colour differences.
- (c) Neuromast organs are little groups of receptor and supporting ectodermal cells found in the lateral line canals. Neuromast organs are current receptor or rheoreceptor and can perceive vibration of very low frequency.
- (a) Jacobson's organ (vomeronasal organ) is concerned with smell.
- (c) Jacobson's organs are present in the anterior part of nasal cavity which is well developed in snakes and lizards while vestigial organ in man.
- (b) A small, bipectinate chemoreceptor called osphradium is present in the mantle cavity of Pila and is sensible to chemical stimulus.
- (d) Meissner corpuscles are specialised sense organs situated immediately beneath epidermis in the skin. These respond to touch and pressure.
- (c) Long stiff tactile hairs, the vibrissae (pili tactiles) project from the side of mouth, external nares and above the eye.
- (d) Proprioceptors are situated internally, and detect changes in the internal environment of body
- (d) Bats produce subsonic sound which are received by ear after being reflected by the surrounding objects. The time taken by the echo indicates the distance of object to bat.
- (b) Proprioceptor are sensory nerve ending located deep with muscles, tendons, joints and vestibular apparatus that respond to stimuli originating from within the body regarding movement and spatial position

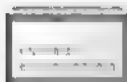


**Eye**

1. (c) Iris is a pigmented disc like part which is found between cornea and lens. Iris consist of circular sphincter and radial dilators muscles which controls the light entering into the eye.
2. (b) Choroid is the middle pigmented and vascular layer in the wall of the eye of a vertebrate between retina and sclerotic coat
3. (c) Rhodopsin is a visual purple pigment (formed by vitamin A and opsin protein) sensitive to dimlight. It helps in twilight vision during night.
4. (d) Fovea is present at centre of macula lutea, which is centre of highest resolution, has only cones
6. (d) In glaucoma, there is over production of vitreous humour which increases the pressure in the eye and this crushes the delicate cells of the retina, causing blindness.
9. (a) Blind spot in the eye is the place where neither rods nor cones present.
13. (a) Vitamin A is the precursor of the purplish red pigment rhodopsin contained in the rods (photoreceptor) cells of human eye.
14. (b) Iodopsin is photosensitive visual pigment found in cones of retina.
20. (b) The muscles associated with the iris regulate the amount of light entering the eyeball by varying the size of the pupil.
28. (a) The eye lens is made of transparent proteins called crystallins. The proteins are arranged in approximately 20,000 thin concentric layers. The average concentration of lens protein is about twice than that of other intracellular proteins & is thought to play a structural role in the lens.
31. (a) Unstriated or non striated or visceral or smooth or involuntary muscles are found in iris of eye, oesophagus, stomach, intestine lungs, urinogenital tract, urinary bladder and blood vessels.
35. (c) Each eye of cockroach is a compound structure of about 2000 ommatidia which are the visual units of photoreception.
36. (c) Myopia is near sightedness. In this defect, the light rays converge in front of retina causing a blurred image.
37. (d) Owl is able to see at night but has poor day vision due to the presence of only rods in eyes.
40. (a) Glucoma develops due to increased intraocular tension as a result of blocking of canal of schlemm. The pressure in eye rises above the normal range of 15-20 mm of Hg since to aqueous humour is not drained out into the blood.
43. (a) Central opening of iris is called pupil which controls the light entering into eye.
46. (d) The posterior part of the retina, which is just opposite to the lens is called area centralis or yellow spot, which contains only cones and has yellow pigment, the images are normally focussed on this area.
47. (c) Fovea centralis, a shallow depression at the middle of yellow spot (macula lutea), has only cone cells and is the place of most distinct vision.
52. (d) Choroid in the middle layer of the eye which is highly vascular and covered with pigment cells.
53. (c) The cones are about 300 times less sensitive than the rods but even this allows colour vision in any light greater than dimlight.
58. (b) Cone cells of retina are related to Photopic vision and also for perception of colours.

**Ear**

1. (c) Pinna collects the sound vibrations and reflect them into external auditory canal. Besides this it also helps in localisation of sound source.
2. (c) The *scala vestibuli* and *scala tympani* are filled up with perilymph and communicates with each other at the apex through a small opening *helicotrema* i.e., *scala vestibuli* is connected with *scala tympani*.
5. (c) Acoustic spots occur in the ampullae of semicircular ducts of internal ear or the membranous labyrinth. The wall of the membranous labyrinth of frog is lined with cubical epithelial cells. The epithelial lining, at certain places, is modified to form sensory patches called acoustic spots. There exists one in the utricle, one in the saccule, and one in the lagens. The sensory paths of ampullae are called cristae, while the other one are known as maculae.
7. (a) These are called the *limits of audibility*. Actual value is 20 to 20000 cycles/sec.
10. (c) Perilymph is clear fluid present in the bony labyrinth of ear.
19. (c) Three auditory ossicles in the middle ear are malleus incus and stapes.
20. (c) The crista and macula are the specific receptors of the vestibular apparatus responsible for maintenance of balance of the body and posture. These play no role in hearing.
23. (c) Hyomandibular is one pair of small cartilages or bone forming the dorsal ends of the hyoid arch of a vertebrate. Hyomendibular becomes modified to form an auditory ossicle the columella auris of amphibia, reptiles and birds and the stapes of mammals.
25. (a) Cochlear branch of auditory nerve supplies the organ of corti.
27. (d) The function of eustachian tube is to equalize air pressure on both side (external and middle ear) of tympanic membrane.



28. (b) The scala vestibuli and scala media are separated by Reissner's membrane which makes up the roof or dorsal wall of the scala media.
29. (b) Organ of Corti is the auditory sense organ within the spiral cochlea of mammalian ear.
30. (d) The otolithic membrane contains numerous minute, irregular particles called otoliths or otoconia which are made up of calcium carbonate and protein.
31. (a) Ear drum is also known as tympanic membrane which separates middle ear from external ear.
34. (a) Rods are sensitive to dimlight.
36. (b) Myopia or near sightedness is related abnormalities of eye in which eye ball becomes elongated, increasing the horizontal axis of eye. The image is formed before retina instead of upon it.
39. (b) The iris of eye can be compared with the diaphragm of a camera as it regulates the amounts of light entering in eye by constricting or dilating the pupil.
43. (c) Many nocturnal mammals also have tapetum lucidum which contain light reflecting crystals of guanine.
44. (b) The cristae of rabbit ear helps in maintaining balance in transverse position of longitudinal axis of semicircular canals.

### Critical Thinking Questions

1. (a) Because cerebellum is not concerned with conscious sensations. It maintains equilibrium.
2. (b) Reflex arc is the pathway taken by nerve impulse generated at the receptors due to stimulus to reach the effector organ during reflex action.
3. (c) Post-ganglionic fibers of parasympathetic nervous system secrete acetylcholine which decrease heart rate and cardiac output.
7. (c) Since the use of a convex lens decreases the focal length of the eye-lens, therefore in this case, the image is formed behind retina when lens is not used
9. (a) The cerebrospinal fluid is secreted by anterior choroid plexus and posterior choroid plexus and is found inside the ventricles of the brain and central canal of the spinal cord
11. (cd) Vagus is 10<sup>th</sup> cranial nerve. It originates from the sides of medulla oblongata. In vertebrates it consists of sensory and motor fibres.
15. (c) Olfactory lobes are concerned with the sense of smell. The senses is very well developed in scoliodon, and dogs.
17. (b) The tectorial membrane overhangs the sensory hair in the scala media. Its properties are to determine the patterns of vibration of sound waves.
19. (d) In white fibres (myelinated) impulse jumps from node to node, it is called saltatory conduction.
22. (a) Synaptic fatigue is a temporary suspension of impulse transmission in the region of synapses due to exhaustion of its neurotransmitter (acetylcholine).
31. (a) Otoconia helps in balancing the body, during the change of posture when the body is imbalanced and tilted onto one side the otoconia touch the stereocilia and bend it causing the generation of nerve impulse.
32. (a) End organ of Ruffini are external receptors of heat present in skin.
45. (a) Cataract defect develops when lens becomes opaque and loses its flexibility, its density increases and it acquires amber colour.
46. (d) Eye can be moved by 6 extrinsic ocular muscles attached to its posterior wall. Two are external and internal oblique muscle while the other four are rectus muscles.
49. (a) Cornea is a transparent layer of tissue, continuous with the sclerotic that forms the front part of the vertebrate eye over the iris and lens. The cornea refracts light entering the eye onto the lens, thus assisting in the focusing of images onto the retina.

### Assertion and Reason

1. (c) To maintain the unequal distribution of  $\text{Na}^+$  and  $\text{K}^+$  ion, the nerves use chemical energy in form of ATP to actively transport  $\text{Na}^+$  ion out of cell and more  $\text{K}^+$  inside the cell
2. (c) Rabies is an overwhelming encephalomyelitis and includes severe headache and high fever with excitement and depression. This disease occurs by a virus called Rhabdovirus.
3. (a) Neurotransmitters need to transmit the nerve impulses through synaptic cleft which is a small part at junction of two neurons.
4. (a) Medulla oblongata consists of accumulation of nerve cells act as vital centres of many autonomic reflexes like vomiting, coughing and sneezing.
5. (b) Anterior lobe of pituitary is called Pars distalis. It is attached to hypothalamus by hypophyseal portal vein. This portal vein called hypothalamo-hypophyseal portal vein.
6. (b) Activity of sense organs is related with two types of neurons (afferent and efferent). The neurons, which pass nerve impulses from the body organ to the brain, is called afferent neuron. The neurons, which pass nerve impulses from the brain to the body organs, are called efferent neurons.

7. (c) An extracellular fluid, called cerebrospinal fluid is present throughout the central nervous system. It affords some protection to central nervous system from injury and shock.
8. (c) The neurons and nerve fibres which conduct nerve impulse from the Central Nervous System (CNS) to the peripheral organs and tissues are called efferent neurons and efferent nerve fibres respectively. Some of the neurons and nerve fibres conduct nerve impulses to the muscles and gland to stimulate or inhibit their activities. Many of these nerve fibres cause movements of muscles. So, such neurons and nerve fibres are known as motor neurons and motor nerve fibres, respectively. The motor nerve fibres are the axons of motor neurons. All motor neurons are efferent neurons, because they conduct impulses from the CNS to the peripheral tissues viz, muscles and gland. The nerve fibres which reach nerve impulses to the eye muscles to control their movements are motor fibres; so also are the fibres carrying impulses to the salivary glands and controlling their secretion.

The nerve impulses are conducted from the spinal cord to the brain by ascending nerve tracts which are the bundles of nerve fibres ascending along the white matter of the spinal cord.
9. (c) The brain and the spinal cord constitute the central nervous system. The areas of the CNS where the cell bodies of the neurons are situated, look grey and constitute the grey matter. Other areas look white and constitute the white matter of the CNS. The white matter contains only nerve fibres cruising from or to the nerve cells in the grey matter. It looks white due to the presence of myelin around the myelinated fibres. In most parts of the brain, the grey matter containing the nerve cells is situated on the surface while the white matter made of fibres is located deep inside the brain; but in the spinal cord, the grey matter is internal and white matter occurs outside.
10. (e) The nervous system of human comprises of Central Nervous System – comprises of brain and spinal cord. Peripheral Nervous System – comprises of nerves present between brain and body parts.
11. (b) The spinal cord extends downwards from the brain stem. The grey matter from a column running along the central part of the spinal canal (= neurocoel, lined with ciliated ependymal epithelium), containing the cerebrospinal fluid, running along the central part of the grey matter. Grey matter is composed of nerve cells, bodies, dendrites and synapses. The white matter forms an outer column surrounding the grey matter at its centre.
12. (a) Our eyes are the sense organs for vision. The light sensitive inner layer of eyeball called retina contain photoreceptors viz. rod and cone cells which convert the energy of specific wavelengths of light into action potentials of nerve fibres. Rods are sensitive even to dim light and consequently enable to see in dim light and at night. They contain a purple coloured photosensitive pigment, called rhodopsin. Rhodopsin consists of the protein scotopsin and retinene, a derivative of vitamin A which is required for proper vision and is required for the regeneration of rhodopsin after it has been exposed to light.
13. (a) Tongue is also called as gustatoreceptor and it is a receptor for taste. The receptor for gustatory sensation are located in taste buds on tongue.
14. (b) The wall of each eyeball is made up of three concentric layer-sclerotic, choroid and retina. The choroid is a highly vascular pigmented layer separating the sclerotic from the inner layer of the eyeball. It is connected in front to a thick structure called ciliary body.

Iris is a pigmented, muscular, opaque diaphragm which extends from the ciliary body in front of a biconvex transparent lens. Iris has a small central aperture called pupil. Light passing through the cornea enters through the pupil to fall on the lens behind it. The iris has two sets of smooth muscles arranged circularly and radially around the pupil. The pupil gets constricted by the contraction of circular muscles to reduce the amount of light falling on the lens. On the contrary, the pupil gets dilated by the contraction of radial muscles to increase the amount of light falling on the lens.
15. (c) The light sensitive inner layer of eyeball called retina contain photoreceptors viz. rod and cone cells which convert the energy of specific wavelengths of light into action potentials of nerve fibres. Cone cells are sensitive to bright light only. So, they help to see in daylight or in a brightly illuminated room by electric lamps. Rod cells are sensitive even to dim light and consequently help to see in dim light and at night. Animals, like sparrows, which are active only in day time, have mostly cone cells in their retina and therefore they possess poor night vision.

Ommatidia are the elongated tube like units of a compound eye present in higher invertebrates like prawns, crabs and insects. Ommatidia are crowded over a spherical surface. Each focusses the light from a small area of the object so that a mosaic of a large number of images of the adjacent areas of the object are formed by numerous ommatidia. A fusion of these images may produce a composite blurred image of the object.
16. (b) The choroid is the middle layer of eyeball which is connected in front to a thick structure called ciliary body. Thread like suspensory ligaments extend from the ciliary body and get attached to a biconvex, transparent elastic Lens. For proper vision, light rays from a visual object must be focussed sharply and precisely on the retina. In the resting eye, the ciliary muscles remain relaxed, keeping the suspensory ligaments stoutly stretched which flattens the elastic lens to reduce its curvature.

The lens in this resting eye focusses parallel rays from distant objects (more than 6 m away) on the retina. But to increase the power of the lens for focussing divergent rays from near object on the retina, a reflex called accommodation is needed. The eye has got the property to form images of both near and far objects on the retina by changing the convexity of the lens. This is known as the power of accommodation.
17. (b)

## Neural Control and Coordination

## ET Self Evaluation Test

1. Which one of these processes is found in animals only [MP PMT 1994]  
(a) Nervous system (b) Hormonal control  
(c) Respiration (d) Diffusion
2. Saltatory conduction occurs in  
(a) Myelinated nerve fibres  
(b) Non-myelinated nerve-fibres  
(c) Both myelinated and non-myelin nerve fibres  
(d) Skeletal muscle fibres
3. Who got the Nobel prize for describing in detail the visual cycle  
(a) Wald (b) Sherrington  
(c) Young (d) Henson
4. The largest cranial nerve of the body is [MP PMT 1999]  
(a) Hypoglossal (b) Vagus  
(c) Glossopharyngeal (d) Olfactory
5. Human eyes are most sensitive to the wave length of  
(a) 1000 Å (b) 5000 Å  
(c) 7000 Å (d) 20 Å
6. The mixed nerve is [CPMT 1994]  
(a) Auditory (b) Oculomotor  
(c) Facial (d) Abducens
7. Diencephalon is not a control centre of  
(a) Heart beat (b) Anger  
(c) Hate (d) Love
8. Which of the following is not found in mammalian brain  
(a) Subdural space (b) Sub-arachnoid space  
(c) Optocoel (d) Duramater
9. Nerve impulse travels by steps [MP PMT 1998; AFMC 2003]  
(a) Chemical in nature  
(b) Chemical and electric in nature  
(c) Physical in nature  
(d) None of the above
10. Which kind of waves are generated in brain during deep sleep [AFMC 2008]  
(a) Alpha wave (b) Beta wave  
(c) Delta wave (d) Theta wave
11. In the central nervous system myelinated fibres form the . . . , while the non-myelinated fibre cells form the . . . [AIIMS 2009]  
(a) Grey matter; white matter  
(b) White matter; grey matter  
(c) Ependymal cells; neurosecretory cells  
(d) Neurosecretory cells; ependymal cells
12. Which of the following are the two extra cranial nerves found in rabbit [CPMT 1993]  
(a) Glossopharyngeal and hypoglossal  
(b) Glossopharyngeal and spinal accessory  
(c) Spinal accessory and hypoglossal  
(d) Pneumogastric and hypoglossal
13. The chief functional units of the nervous system are [NCERT; DPMT 1993; MP PMT 1995; Pb. PMT 2004]  
(a) Neuroglia (b) Axon  
(c) Neurons (d) Dendrites
14. Which one of the following is spinal nerve [CPMT 1998]  
(a) Hypoglossal (b) Trigeminal  
(c) Olfactory (d) None of these
15. Which of the following is an example of conditioned reflex [BHU 1999]  
(a) Cycling  
(b) Withdrawal of hand on touching a hot plate  
(c) Watering of mouth at smell of food  
(d) Flowing of tears while cutting onions
16. If parasympathetic nerve of the rabbit is cut then heart beat [RPMT 2001; MHCET 2002]  
(a) Unaffected (b) Decreases  
(c) Increases (d) Stop
17. Name the cranial nerves of humans being viz., II, VII, VIII, IX [Odisha PMT 2002]  
(a) Optic, auditory, facial, hypoglossal  
(b) Oculomotor, auditory, abducens, hypoglossal  
(c) Optic, facial, auditory, glossopharyngeal  
(d) Optic, facial, abducens, glossopharyngeal
18. Which set of ions are required during conduction of the nerve impulse [CBSE PMT 1991; AFMC 1995]  
(a) Na and Ca (b) Ca and Mg  
(c) Na and K (d) Na and Mg
19. The rate of conduction in myelinated fibre of a mammal is very high because [CPMT 1992]  
(a) Synapses are less frequent  
(b) Action potential is faster and numerous  
(c) Action potential jumps from node to node  
(d) Membrane is depolarised faster
20. The sequence of ear ossicles starting from the ear drum is [DPMT 1993; Pb. PMT 2000; MP PMT 2001; AFMC 2004; BHU 2005]  

Or

What is the right sequence of bones in the ear ossicles of a mammal starting from the tympanum inwards

Or

The sequence of ossicles starting from outside to inside [DPMT 2007]

(a) Malleus, incus, stapes (b) Incus, malleus, stapes  
(c) Malleus, stapes, incus (d) Stapes, incus, malleus
21. The chemoreceptors in the body are  
(a) Proprioceptors (b) Meissner's corpuscles  
(c) Olfactory and taste organs (d) Free nerve endings

22. Which of the following use Radar systems in detecting the target  
(a) Birds (b) Bats  
(c) Dogs (d) Bats and dogs
23. Organs of corti are present in the cavity known as  
[NCERT; CPMT 1992, 93; MP PMT 1992, 2003, 04]  
(a) Scala tympani  
(b) Helicotrema  
(c) Reissner's membrane  
(d) Scala media (Cochlear canal)
24. Anosmia is  
(a) Related to ear disease (b) Related to eye disease  
(c) Related to tongue (d) Loss of sense of smell
25. The membranous labyrinth is concerned with  
(a) Hearing (b) Balancing  
(c) Sound production (d) Hearing and balancing
26. A receptor  
(a) Is the first segment of a reflex arc  
(b) Initiates nerve impulses  
(c) Responds to only one type of stimulation  
(d) All of these
27. Which of the following sense organs are unique in fishes (Scollodon) [KCET 1999; CPMT 2003; MHCET 2004]  
(a) Optic organs (b) Olfactory organ  
(c) Muscle system (d) Lateral line sense organs
28. Ear is most sensitive to  
(a) 20 cycles/sec (b) 1,000 cycles/sec  
(c) 10,000 cycles/sec (d) 40,000 cycles/sec
29. In mammals, the lacrimal glands are concerned with secretion of [HP PMT 2005]  
(a) Hormones (b) Digestive juices  
(c) Enzymes (d) Tears
30. The malleus, incus and stapes are the modified bones of .... respectively [MP PMT 2004]  
(a) Articular, hyomandibular and quadrate  
(b) Quadrate, articular and hyomandibular  
(c) Articular, quadrate and hyomandibular  
(d) Quadrate, hyomandibular and articular

## Answers

1	a	2	a	3	a	4	b	5	b
6	c	7	a	8	c	9	b	10	c
11	b	12	c	13	c	14	d	15	a
16	c	17	c	18	c	19	c	20	a
21	c	22	b	23	d	24	d	25	d
26	d	27	d	28	b	29	d	30	c

\* \* \*



## Chapter 5.7

# Chemical Co-ordination and Integration

Endocrine system is formed of all endocrine glands of body. Though different endocrine glands are different in embryonic origin and are isolated from one another but these interact with one another so collectively form an endocrine system. Endocrine system along with nervous system, controls and coordinates the body functions and maintains a homeostasis. So both collectively form neuro-endocrine system. The study of these two systems is called neuro-endocrinology.

**Glands of body :** Animals have three types of glands.

(i) **Exocrine gland** (Gr., *ex* = out + *krinein* = to secrete) : These glands have ducts for discharging their secretions. Therefore, they are called as duct glands. *ex* – Liver, Sweat gland, Sebaceous gland, Gastric glands and some intestinal glands.

(i) **Endocrine glands** (Gr., *endo* = within + *krinein* = to secrete) : These glands lack ducts and pass secretions into the surrounding blood directly. Therefore they are called as ductless glands. *ex* – Thyroid, parathyroid, adrenal, pituitary, pineal body and thymus.

(iii) **Heterocrine glands** : These glands consist of both exocrine and endocrine tissue. The exocrine discharge its secretion by a duct and the endocrine tissue discharges its secretion into the blood. Pancreas and gonads are heterocrine glands. These are also called mixed glands.

### Hormones and their mechanism

Hormones are informational molecules secreted by the endocrine cells in one part of the body and carried by blood to another part where they stimulate or inhibit specific physiological process.

**Discovery** : First hormone discovered was secretin. It was discovered by two English physiologists : William M Bayliss and Ernest H. Starling in 1903.

Term hormone was coined by Starling (1905) from Greek word *Homone* means to excite. It is a misnomer because a number of hormones are known to have inhibitory effect (e.g., Somatostatin).

### General function of hormones

(1) Some hormones control Basal Metabolic Rate (BMR) e.g., thyroxine of thyroid gland.

(2) Some hormones control the secretion of other endocrine glands, e.g., Tropic hormones of Anterior pituitary control Thyroid, Adrenal cortex, gonads, etc.

(3) Some hormone control blood pressure e.g., Aldosterone, Atrial Natriuretic Hormone (ANH) of heart, Vasopressin or ADH, oxytocin and Renin of kidney.

(4) Increase production of RBC e.g., erythropoietin of kidney.

### Properties of hormones

(1) These are secreted by endocrine gland (biogenic in origin).

(2) Their secretions is released directly into blood (except local hormones e.g., gastrin)

(3) These are carried to distantly located specific organs, called target organ.

(4) These have specific physiological action (excitatory or inhibitory). These co-ordinate different physical, mental and metabolic activities and maintain homeostasis.

(5) The hormones have low molecular weight e.g., ADH has a molecular weight of 600–2000 daltons.

(6) These act in very low concentration e.g., around  $10^{-10}$  molar.

(7) Hormones are non antigenic.

(8) These are mostly short-lived. So have a no cumulative effect.

(9) Some hormones are quick acting e.g., adrenalin, while some acting slowly e.g., oestrogen of ovary.

(10) Some hormones secreted in inactive form called Prohormone e.g., Pro-insulin.

(11) Hormones are specific. They are carriers of specific information to their specific target organ. Only those target cell respond to a particular hormone for which they have receptors.

(12) Hormones after their action are destroyed in liver and kidney.

#### Classification of hormones

(1) **On the basis of chemical nature** : On the basis of chemical composition hormones are classified into three categories.

(i) **Amine hormones** : These are derived from tyrosine amino acid and have amino ( $-NH_2$ ) group *e.g.*, Thyroxine, Epinephrine, Nor-epinephrine.

(ii) **Steroids** : These are fat soluble and have sterol group. These are derived from cholesterol *e.g.*, hormones of adrenal cortex (cortisol, cortisone, corticosterone, aldosterone) testes (testosterone) and ovaries (oestrone, oestradiol, progesterone etc.)

(iii) **Proteinaceous and peptide hormones** : These are formed of 3 – 200 amino acids interlinked by peptide bonds and are water soluble *e.g.*,

(a) Proteinaceous hormones like STH, TSH, FSH, LH etc. Out of these FSH and LH are glycoproteins.

(b) Long peptide hormones like insulin and glucagon, ACTH, Parathormone.

(c) Short peptide hormones like oxytocin, ADH, MSH. These hormones formed of a few amino acids

#### (2) On the basis of mode of action

(i) **Quick acting hormones** : These hormones initiate immediate response from their target cells. Their receptor is always located on the outer surface of plasma membrane of target cell because these are large sized. Hormone receptor complex activates a membrane enzyme adenyl cyclase which hydrolyse ATP into cyclic AMP. Which acts as secondary messenger, c-AMP activates an inactive enzyme system by cascade effect. So their mode of action is called second messenger hypothesis. *e.g.*, These include proteinaceous, peptide and amine hormones.

(ii) **Delayed acting hormones** : These hormones initiate response after some time. These are small sized so are diffusible through the plasma membrane of their target cell. These bind their proteinaceous receptor present in the cytosol. These always operate through de-novo synthesis of m-RNA by activation of certain genes. So their mechanism of action is called m-RNA hypothesis. These include steroid hormones of testes, ovary and adrenal cortex.

**Table : 5.7-1 Difference between hormone and enzymes**

S.No	Characters	Enzymes	Hormones
1.	Chemistry	Always proteinaceous	May be proteinaceous, or amine or steroids.
2.	Molecular weight	Macromolecules with high molecular weights.	Have low molecular weights.
3	Diffusibility	Non-diffusible through cell membrane.	Diffusible through cell membrane
4	Site of action	Either act intracellularly or carried by some duct to another site	Generally carried by blood to a target organ
5.	Mode of action	Always act as biocatalysts and increase the rate of metabolic physiological process	May be excitatory or inhibitory in their physiological action.
6	Reversibility	These catalyze reversible reactions	Hormone controlled reactions are not reversible
7	Effect of concentration	Reaction rate increase with increase in their concentration upto a limit	Deficiency or excess of hormone causes metabolic disorders and diseases.
8.	Speed	Act quickly	Some are quick acting, while some are slow acting with a lag period
9.	Consumption	Not used in metabolic functions.	Used up in metabolic functions.

**Table : 5.7-2 Difference between hormone and vitamin**

S.No.	Characters	Hormones	Vitamins
1	Source	Synthesized in the endocrine cells of body	Taken along with food from outside
2	Chemistry	Steroids or proteinous or amino acid derivatives	Simple organic compounds like amines, esters, organic acids etc
3	Action	Either excitatory or inhibitory Do not act as co-enzymes	These generally act as co-enzymes for enzyme activity
4	Cause of disorders	Both excess as well as deficiency of hormones	Generally avitaminosis deficiency of vitamins, leads to deficiency diseases.

**Table : 5.7-3 Difference between Nervous and hormonal control**

S No.	Characters	Nervous control	Hormones control
1	Speed of action	Always quick acting	May be quick acting or acting with a long period
2	Mode of transmission of informations	As electrochemical nerve impulses.	As chemical messengers.
3	Path of transmission	Through nerve fibres.	Through blood
4	Direction of the informations	Towards a specific direction (effector organ or CNS)	Released in general blood circulation from where taken by specific receptor.
5	Suitability	For quick reactions like reflexes	For long term changes <i>e.g.</i> maintenance of pregnancy
6.	Durability	Short time effect.	Long lasting.

**Release of hormones** : Hormones are released from endocrine glands by three types of stimuli.

(1) **Specific metabolites** : The presence of a specific metabolite in the blood elicits the hormone to deal with it.

For instance excess of glucose in the blood causes the release of insulin from the pancreas and decrease of glucose in blood causes the release of glucagon from pancreas.

(2) **Other hormone** : The presence of a specific hormone in the blood induces the release of another hormone. For example TSH stimulate thyroid gland to release thyroxine hormone and ACTH stimulate Adrenal cortex to release their hormones.

(3) **Neuronal impulse** : Neurons of autonomic system stimulate hormone release from some glands. For example adrenaline and nor-adrenaline are released from adrenal medulla on the arrival of nerve impulses during anxiety, stress and danger.

**Mechanism of hormone action** : The hormones act in two ways –

(1) **On cell surface** : The molecules of hormones that are amino acid derivatives, peptides or proteins are large and insoluble in lipid, and can not enter the target cell. Therefore they act at the cell surface. They bind to specific receptor molecules located on the surface of cell membrane. The hormone receptor complex may act in one of the two ways –

(i) **Formation of cAMP** : Mechanism of formation of cAMP was discovered by E.W. Sutherland in 1950. The hormone receptor complex causes the release of an enzyme adenylyl cyclase from the receptor site. This enzyme hydrolyse the ATP into c-AMP. The c-AMP activates the existing enzyme system of the cell. This accelerates the metabolic reactions in cell. The hormone is called first messenger and the c-AMP is termed the second messenger. e.g., Adrenaline causes the secretion of glucose from the liver cell from this mechanism.

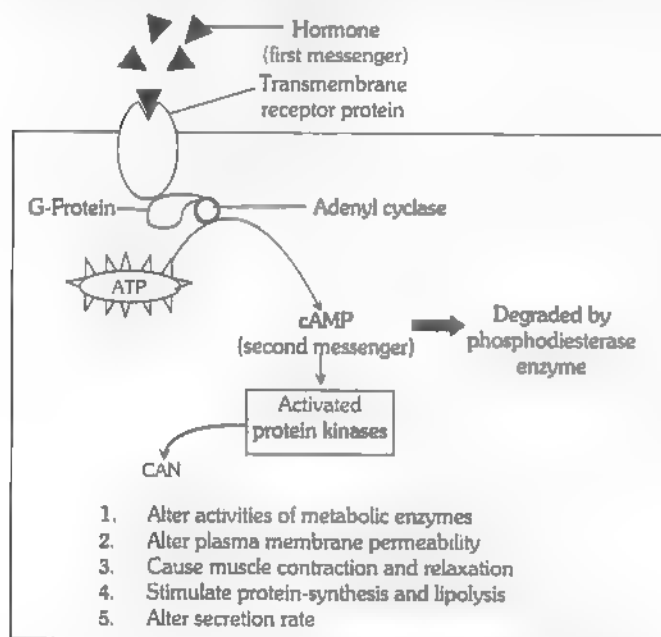


Fig : 5.7-1 Mechanism of Hormone action on cell surface

(i.) **Change in membrane permeability** : The receptor proteins of some hormones are large transmembrane intrinsic protein acting as ion channels for facilitated diffusion of  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$  etc. On binding with specific hormone these receptor proteins undergo conformational changes, so that the membrane permeability for ions is altered, resulting into important changes in metabolism.

For example, insulin promotes the entry of glucose from blood into the muscle cells by increasing the permeability of sarcolemma to glucose.

(2) **Within a cell** : The steroid hormones act within the cell. Their small, lipid soluble molecules pass through the cell membrane and bind to specific receptor molecules present in the cytoplasm. The receptor molecules carry them into the nucleus. Here, the receptor hormone complex binds to a specific receptor site on the chromosome and activates certain genes that were previously repressed. The activated gene transcribe m-RNA which directs the synthesis of enzyme (protein molecule) in the cytoplasm. The enzyme molecule promote the metabolic reactions in the cell

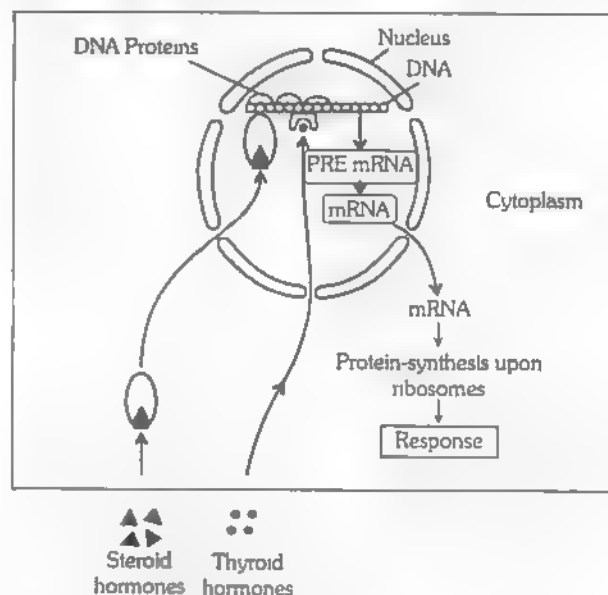


Fig : 5.7-2 Mechanism of cell surface within a cell

**Feedback control of hormone secretion** : The secretion of hormones depends on age, daily routine, health of body, physiological conditions of body etc. Besides the above factors hormone secretion also depends on its own amount circulating in the blood. Decrease and increase in the circulating amount of a hormone has a directly inverse effect on the secretion of hormone. This is known as the "pull and push" or "feed-back control" mechanism of hormonal secretion.

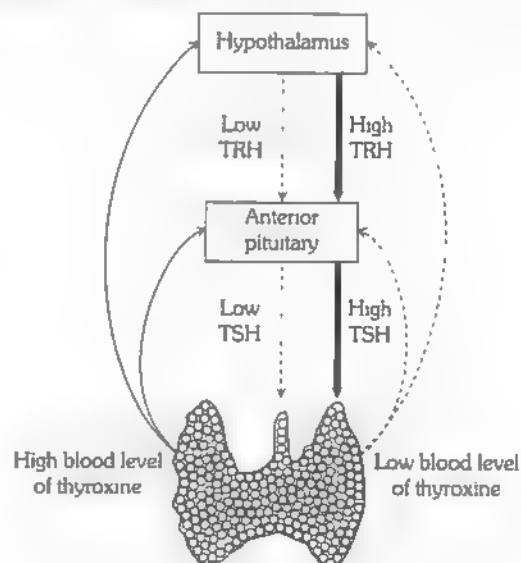


Fig : 5.7-3 Feed-back control of hormone secretion



**(1) Negative feedback control**

**Direct feedback control :** Thyroid stimulating hormone (T.S.H.) stimulates the thyroid gland to secrete thyroxine hormone. A high amount of thyroxine in the blood exerts an inhibitory effect on pituitary to secrete less T.S.H.. This eventually results in decrease in thyroxine. This is called "Direct feedback control".

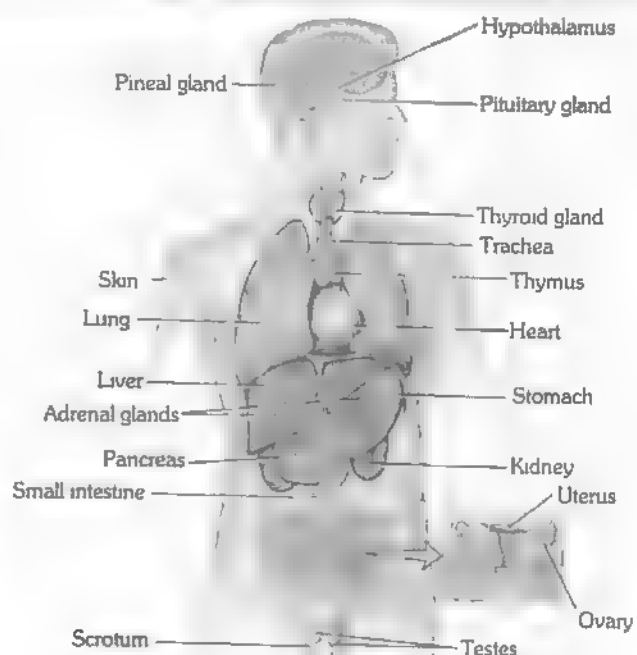
**(2) Positive feedback control :** Oxytocin released by posterior pituitary gland stimulate contraction of uterus during child birth. As the contraction of uterus progresses, more and more of oxytocin is released. This is called positive feed back control.

**Table : 5.7-4 Origin of different endocrine glands**

Endocrine glands	Weight	Origin
Pituitary	0.5 gm	Ectoderm
Pineal	5.0 mg	Ectoderm
Thymus (upto 12 yrs.)	20.0 gm	Endoderm
Thyroid	25.0 gm	Endoderm
Parathyroid	20.0 mg	Endoderm
Adrenal cortex	4.0 gm	Mesoderm
Adrenal medulla	1.0 gm	Ectoderm
Testes	—	Mesoderm
Ovary	—	Mesoderm
Pancreas	60.0 gm	Endoderm

**Table : 5.7-5 Number of hormones secreted by different endocrine glands**

Endocrine-glands	Number of secreted hormones	
Pituitary – Anterior	—	7
Hypothalamus	—	2
Pineal body	—	2
Thymus	—	3
Thyroid	—	2
Parathyroid	—	1
Islets of Langerhans	—	3
Adrenal cortex	—	46
Adrenal medulla	—	2
Testes	—	1
Ovary	—	3
Placenta	—	2
Kidneys	—	2
Stomach	—	1
Duodenum	—	5
Ileum	—	2

**Fig : 5.7-4 Location of many endocrine glands****Discovery & Terms**

- (1) Term 'endocrine' was first used by Claude Bernard.
- (2) Thomas Addison is called as father of endocrinology.
- (3) Walter canon stated that the hormones maintain homeostasis in the body
- (4) Von Euler coined the term 'prostaglandin'
- (5) Kendall for the first time prepared the crystals of thyroxine.
- (6) Hamington and Barger studied the molecular structure of thyroxine.
- (7) Term 'thyroxine' was coined by Whartson.
- (8) Sutherland discovered cAMP.
- (9) Parathormone was first isolated by Collip.
- (10) Potts discovered the structure of PTH.
- (11) Axelord studied the structure of epinephrin and nor-epinephrin.
- (12) Endocrine structures of the pancreas were discovered by langerhans.
- (13) Structure of insulin was studied by Sanger. He was given Nobel prize in 1958. He was rewarded Nobel prize in 1980 for gene structure.
- (14) Human insulin was synthesized by Tsan.
- (15) Glucagon was discovered by Kimball and Murlin.
- (16) Term 'Secretin' was coined by Beylis and Starling
- (17) Adrenal gland was discovered by Eustachian.

## Pituitary Gland (Hypophysis)

Pituitary is known as hypophysis cerebri, its name pituitary was given by Vesalius. Muller's gland of amphioxus and subneural gland of hardmanian is homologous to pituitary of vertebrates. Weight of pituitary is 0.5 gm. Removal of pituitary is known as hypophysectomy.

**Position and origin :** Pituitary gland is the smallest (about 1 to 1½ cm in diameter) endocrine gland of the body. It is pea-shaped, ovoid, reddish brown gland situated at the base of the brain in a cavity, hypophyseal fossa of the sella turcica of sphenoid bone. It is connected by a short stalk called Infundibulum, to the ventral wall (Hypothalamus) of diencephalon. That is why it is also called hypophysis cerebri. It weight about 0.5 to 1 gm. It control most of the endocrine glands. Hence, it is also called leader of endocrine orchestra or master gland. Pituitary gland is closely related with hypothalamus, hence, it is also called hypothalamo-hypophyseal gland, pituitary is ectodermal in origin.

### Parts and component

#### Adenohypophysis

- (1) Pars distalis
  - (2) Pars tuberalis
  - (3) Pars intermedia
- } Anterior lobe 75%

#### Neurohypophysis

- (1) Pars nervosa
  - (2) Infundibulum
- } Posterior lobe 25%

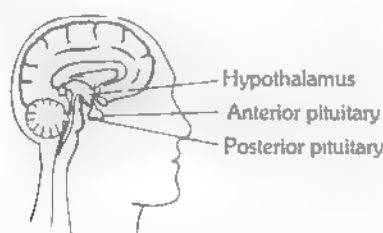


Fig : 5.7-5 Location of pituitary gland

**Structure of pituitary gland :** Pituitary gland is comprised of two main lobes – Adenohypophysis and Neurohypophysis. Adenohypophysis arises as hypophyseal or Rathke's pouch from dorsal wall of embryonic stomodeum. It is the anterior lobe of pituitary. The neurohypophysis (Pars nervosa or Posterior lobe) form as an outgrowth from the infundibulum of the floor of hypothalamus.

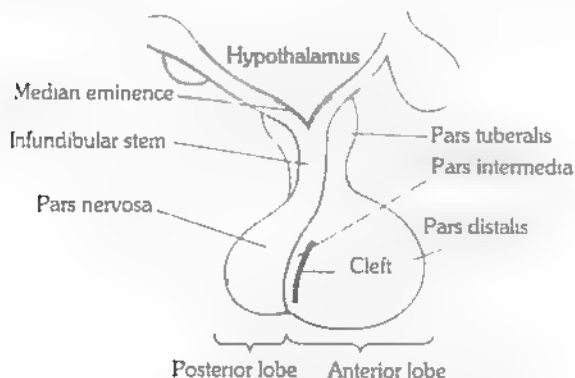


Fig : 5.7-6 Structure of pituitary gland

In pituitary following types of cells are found :

(1) **Chromophobes cells :** Found in adenohypophysis of pituitary. These are not stained by acid and base dye. Pigment granules are absent. These are colourless may change into chromophils.

(2) **Chromophil cells :** Found in adenohypophysis of pituitary. These are stained by acid and base dye. Pigment granules are filled in these cells. These may be two types :

(i) **Acidophils :** It is also known as  $\alpha$ -cells synthesize and secretes growth hormone and prolactin.

(ii) **Basophils :** It is also known as cyanophils or  $\beta$ -cells synthesize and secretes TSH, ACTH, FSH, LH and MSH hormones

(3) **Pituicyte cells :** These cells found in neurohypophysis of pituitary. These are supporting neuroglia cells and gives support to herring bodies.

(4) **Herring bodies :** Herring bodies are dilated terminal portion of Neurosecretory axon constituting hypothalamohypophyseal tract. They are hormone precursors for oxytocin and vasopressin.

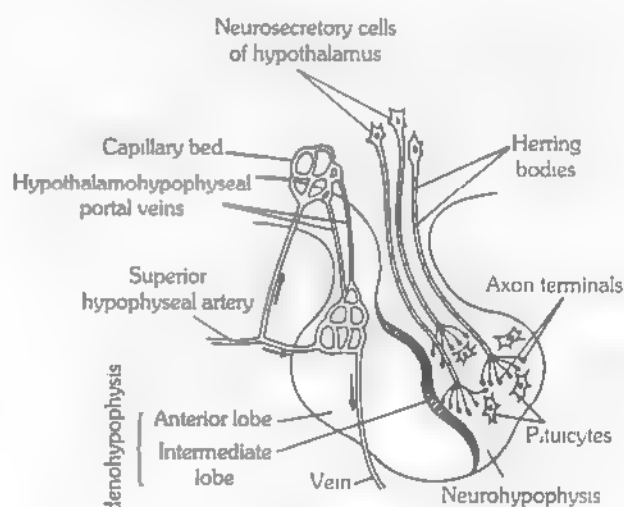


Fig : 5.7-7 Blood supply to pituitary

**Blood supply to pituitary or Hypophyseal portal system :** A pair of posterior hypophyseal arteries and a pair of anterior hypophyseal arteries provide blood to the pituitary gland. Posterior arteries supply blood to the pars nervosa, and anterior arteries supply blood to the hypothalamus and pars distalis. Adenohypophysis has dual blood supply by means of a "circle of willis". The anterior hypophyseal artery which bring blood into this circle big ureates into two branches outside the lobe. One branch supplies the adenohypophysis and other supplies the hypothalamus. The veins that drain the blood from hypothalamus. Then run into the pars distalis through pars tuberalis and divide into capillaries. Those veins are therefore, called portal hypophyseal veins. These constitute a hypothalamo hypophyseal portal system. Hypothalamic hormone reached anterior pituitary by portal system

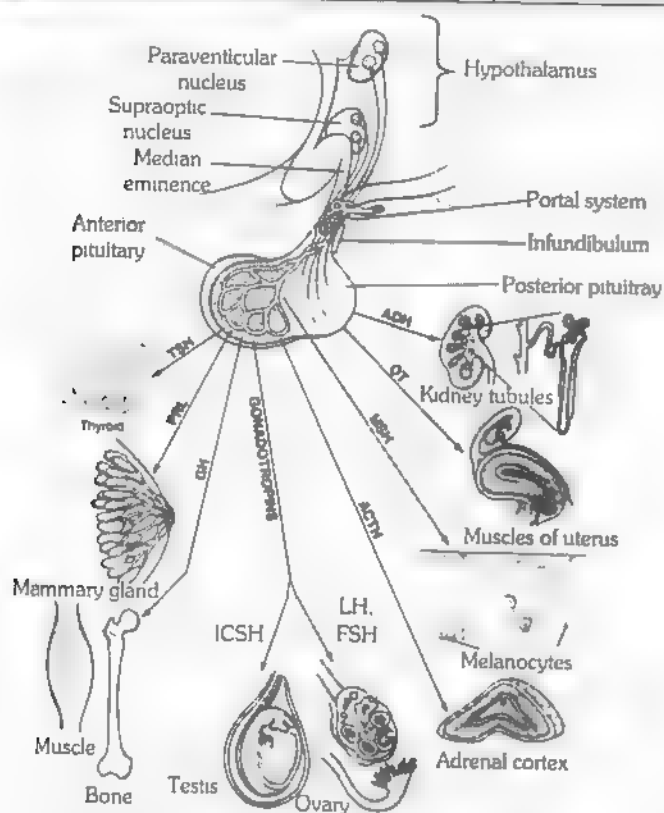


Fig : 5.7-8 Diagram to show the hormones of adenohypophysis and their target tissues and organs

### Hormones of adenohypophysis

Adenohypophysis secretes seven hormones which are proteinaceous in nature. These hormones are controlled by the controlling factors, secreted by the hypothalamus. There are 9 main controlling factors. Out of them 7 are releasing factors (RF) and 3 are inhibiting factor (IF). Complete failure of adenohypophysis (ant. pituitary) leads to simmonds syndrome. Hormones that influence another endocrine gland are called tropic or tropin hormones. The FSH/LH regulate testes and ovaries, thyrotropin stimulate thyroid, whereas corticotropin act on cortex of adrenal gland. Various hormones of adenohypophysis are as follows -

#### (1) Somatotropin (STH) or Growth Hormone (GH)

(i) **Functions of growth hormone :** Molecules of this hormone are polypeptides of 191 amino acid monomers. It is the major hormone in the secretion of anterior pituitary. It is the most important stimulant of proper normal growth of body. It promotes biosynthesis of DNA, RNA and proteins in all body cells. thus, it acts as an anabolic growth factor. Obviously, it stimulates cellular growth and proliferation, growth and repair of bones, muscles and connective tissue. In the liver cells it promotes, glycogenesis, deamination and gluconeogenesis

According to modern scientists, the anabolic effects of growth hormone in man are indirect, instead of being direct. This hormone triggers synthesis of certain special, insulin-like growth factors (IGFs) in cells of many tissues, such as liver, muscles, cartilages, bones, etc. These growth factors are called somatomedins.

(ii) **Control of the secretion of growth hormone :** Secretion of growth hormone is controlled by two hormonal factors secreted by cells of hypothalamus. One of these factors, called GH-release hormone (GHRH) promotes secretion of growth hormone, while the other called GH-inhibitory hormone (GHIH) retards the secretion of growth hormone by the anterior pituitary. GHRH is also called somatotropin and GHIH is called somatostatin.

#### (iii) Effects of hyposecretion of growth hormone

(a) **Nanism or ateliosis :** Hyposecretion (undersecretion) of growth hormone in childhood results into a blunted growth of body. Growth of all organs is retarded. Growth of bones at their epiphyseal ends stops. Hence, the bones do not grow in length, so that the body remains a dwarf. This pituitary dwarfism is called nanism or ateliosis.

(b) **Midgets :** Unlike the thyroid cretinism, the development of brain is normal in pituitary dwarfs, but like thyroid cretinism, the pituitary dwarfs are also infertile. The dwarfs of circuses are pituitary dwarfs. these are called midgets.

(c) **Pituitary myxoedema :** Undersecretion of growth hormone during adolescence (between 13 to 22 years of age) restricts body height, so that the person remains short-statured. Undersecretion after growth period (about the age of 22) causes pituitary myxoedema whose symptoms are almost similar to those of thyroid myxoedema. These include old age symptoms, such as reduced BMR and protein synthesis, greying and falling of hair, pallor and dryness of skin, reduced BP and low body temperature, insomnia, and weakness of muscles, vision and wisdom. Due to accumulation of mucus under the skin, the body becomes puffy, but weak. Genitalia weaken, causing sexual disability. Hence, the person becomes disheartened.

#### (iv) Effects of hypersecretion of growth hormone

(a) **Proportionate gigantism :** Hypersecretion (oversecretion) of growth hormone during growth period (childhood and adolescence) causes excessive growth (hypergrowth) of all body parts, resulting into a symmetrically giant body. This is called proportionate gigantism.

(b) **Disproportionate gigantism or acromegaly :** The concerned person may attain a height of 8 feet or ever more. Oversecretion of growth hormone after growth period also causes gigantism, but in this the long bones do not grow in length due to closed epiphyseal plate at their ends, but the bones of hands, feet, lower jaw and rib cage thicken. Simultaneously, eyelids, lips, tongue, nose, chin, etc also enlarge. Soles, palms and forehead become wrinkled. Skin thickens and becomes coarse and fluffy (hirsutism).

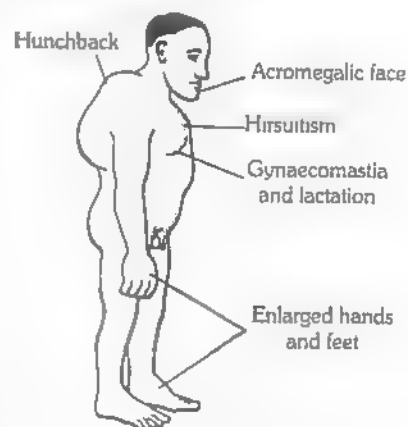


Fig : 5.7-9 A typical case of acromegaly and forehead become wrinkled. Skin thickens and becomes wrinkled. Skin thickens and becomes coarse and fluffy (hirsutism).

Consequently, the body becomes ugly like a gorilla. This is called disproportionate gigantism or acromegaly. It is common in men and rare in women.

(c) **Kyphosis** : In some cases, the backbone bends and thickens, causing hunchback condition (kyphosis). Breasts enlarge and mammary gland may yield milk. The patients often complain of headache, sexual disorders, muscular pain, and impaired vision and memory.

(d) **Diabetes mellitus** : Hypersecretion of growth hormone raises blood glucose level (*hyperglycemia*) which may cause diabetes mellitus.

(e) **Ketosis** : Increased breakdown of fat may release ketone bodies, mainly acetoacetic acid, in blood, causing ketosis.

(2) **Prolactin (PRL), Lactogenic, Luteotropic (LTH), or Mammatropic (MTH) Hormone** : It is secreted by the lactotroph cells of anterior pituitary. Its molecules are polypeptides of 198 amino acid monomers. Its secretion by anterior pituitary is enhanced by prolactin-release hormone (PRH) and suppressed by prolactin inhibitory hormone (PIH) of hypothalamus. PIH is also called dopamine. In humans, it may act as a mild growth hormone, but its main physiological effect is to activate growth of breasts during pregnancy and secretion of milk by mammary glands after childbirth. That is why, it is often referred to as "maternity hormone". In some other mammals, and probably in women also, it stimulates corpus luteum of ovaries to continue secreting progesterone, hormone during pregnancy. Prolactin levels rise during pregnancy due to PRH of hypothalamus.

**Hypersecretion** : (i) Prolactin hormone is secreted both in males as well females. In males it influence sexual behaviour. Its hypersecretion may hinder menstruation.

(ii) May cause impotency

(iii) In pigeons and doves, it stimulates the epithelial cells of crop in both males and females to secrete "pigeon milk" for nutrition of newly hatched infants.

(3) **Follicle-stimulating hormone (FSH) or Gametokinetic factor** : It is a glycoprotein whose molecules consists of a polypeptide of 204 amino acid residues. It stimulates growth of seminiferous tubules and spermatogenesis in men, and growth of ovarian follicles and oogenesis in women. In women, it also stimulates secretion of female sex hormones (oestrogens) by the cells of ovarian follicles. Under the negative feedback regulation, the principal male (testosterone) and female (oestradiol) hormones retard secretion of FSH. In women, the effect of FSH on ovaries considerably decreases after the age of 40. Consequently oogenesis, secretion of oestrogens and menstruation decline and ultimately stop. Termination of menstruation is called menopause. GnRH (gonadotropin-releasing hormones) from hypothalamus stimulates FSH release. There is no gonadotropin inhibiting hormone.

(4) **Luteinizing hormone (LH), or Interstitial cell-stimulating hormone (ICSH)** : This is also a glycoprotein whose molecules contain a polypeptide of 204 amino acid residues. In men it stimulates the growth and function of the interstitial cells of testes (cells of Leydig), which secrete the male hormones (androgens) to regulate the development of secondary

sexual characteristics. In women, it stimulates the last stages of oogenesis, ovulation, development of corpus luteum and secretion of progesterone by the corpus luteum. Secretion of LH, like that of FSH is controlled by gonadotropin-releasing hormone (GnRH).

Both FSH and LH are secreted by the gonadotroph cells of anterior pituitary. Since both of these stimulate growth and activities of gonads, these are called gonadotropic hormones. These also activates the accessory genital organs. Secretion of these hormones begins only two to three years before puberty (age of sexual maturity – 12 to 14 years). Obviously their secretion is initiated by a "Genetic biological clock", located in hypothalamus. Further, the secretion of FSH in women are also regulated by a "Clock", located hypothalamus. Further, the secretion of FSH in women are also regulated by a "Clock of menstrual cycle". Under the regulation of both these clocks a gonadotropin-release hormone (GnRH) is secreted by hypothalamus and influences the activities of pituitary gonadotroph cells. Synthetic hormones of this category and their antagonists are now used to respectively activate or retard the activities of gonads.

(5) **Adrenocorticotropin or Adrenocorticotrophic hormone (ACTH)** : It is secreted by corticotroph cells of anterior pituitary. Its molecules are 39 amino acid polypeptides. Its secretion is prompted by a corticotrophin-release hormone (CRH) of hypothalamus. Its role is to intensify synthesis of adrenal cortical hormones, particularly the glucocorticoids. Secretion of ACTH is stimulated by low blood level of glucose, shock conditions and presence of a compound called interleukin-1 (IL-1) secreted by macrophages. Under a direct negative feedback regulation, the concentrations of glucocorticoids in blood affect the secretion of both ACTH and CRH. Hyposecretion of ACTH leads to rheumatic arthritis.

(6) **Thyrotropin or Thyroid-stimulating hormone (TSH)** : It is also a glycoprotein secreted by thyrotroph cells of anterior pituitary. The polypeptide of its molecule has 201 amino acid residues. Its secretion is stimulated by a hypothalamic thyrotrophin-release hormone (TRH). It promotes growth and function of thyroid gland. Under the negative feedback regulation, the secretion rate of hypothalamic TRH depends on blood levels of TSH, thyroxine and glucose, and on metabolic rates of body cells. There is no thyrotropin-inhibiting hormone.

(7) **Melanocyte-stimulating hormone (MSH) or Melanotropin** : It was formerly called intermedin secreted by pars intermedia. This may be the condition in other vertebrates, but in humans, it is secreted by remnant cells of this lobe, which become a part of pars distalis. Its molecule is a small peptide of 13 amino acid residues. Its secretion is controlled by hypothalamic hormones, viz MRH (Melanocyte releasing hormone) and MIH (Possibly oxytocin is released at this time by posterior pituitary of both mother and the fetus. At actual Melanocyte inhibiting hormone). In lower vertebrates, the target cells of this hormone are the melanophores. Melatonin is antagonistic to melanocyte stimulating hormone MSH affects spreading of the melanin granules in these cells so that skin colour darkens in fish and amphibian but in birds and mammals of the role of MSH is uncertain. In man, presence of MSH receptor in brain suggests it may influence brain activity.

(8) **Metabolic hormone (MH)** : It influence carbohydrate and fat metabolism of body. The hormone which influence carbohydrate metabolism is known as diabetogenic hormone. The hormone which influence fat metabolism is known as ketogenic hormone.

### Hormones of neurohypophysis and their functions

The herring bodies of neurohypophysis contain two hormones – vasopressin and oxytocin – which are released from axon terminals by exocytosis and diffuse into adjacent blood capillaries when needed. These are secreted by paraventricular nucleus and supra-optic nucleus respectively. Both vasopressin and oxytocin are proteinous in nature.

(1) **Vasopressin** : The principal role of this hormone is to promote reabsorption of water from the distal convoluted tubules of nephrons and collecting ducts reducing excretion of water in urine (diuresis). That is why, it is also called antidiuretic hormone (ADH). Its release into blood is controlled by an "osmoregulatory centre" located in hypothalamus. Another effect of vasopressin is to increase blood pressure by contracting blood vessels (vasoconstriction) in several tissues; hence the name vasopressin.

#### Effect of vasopressin

(i) Vasoconstriction of the blood vessels of skin by this hormone retards secretion of sweat glands

(ii) It also stimulates contraction of intestinal smooth muscles.

(iii) When vasopressin is released in excessive amounts, the urine becomes concentrated and blood is diluted, increasing BP.

The osmo-regulatory centre, then, issues motor impulses to check release of vasopressin.

(iv) When vasopressin is released in smaller amounts, diuresis increases; urine becomes diluted and blood becomes concentrate, amounts, diuresis increase; urine becomes diluted and blood becomes concentrated, decreasing BP

(v) In acute diuresis, quantity of urine may increase to about 20 litres instead of normal 1 to 2 litres per day. This condition is called polyuria or diabetes insipidus (passing of watery; tasteless urine). It causes dehydration of body and thirst.

(2) **Oxytocin (Child birth hormone)** : This hormone stimulates contraction of uterine muscles, inducing labour pains for child birth (parturition) when secretion of progesterone hormone from the placenta declines, making the end of pregnancy. As the sensory impulse of increasing labour pain reaches hypothalamus, more and more oxytocin is released from posterior pituitary under a positive feedback regulation, it dilates the cervix (vaginal stretching). After childbirth, it helps in normalization of the uterus and contracts breast muscles and lactic ducts to facilitate release of milk (lactation) during sucking oxytocin stimulates milk ejection so has a galactogogic effect.

**Master gland** : As is clear from above account, the pituitary gland plays most important regulatory role in the body. Besides regulating growth, sex and general behaviour, it also regulates the secretory activities of other principal endocrine glands and cells. Most appropriately, therefore, pituitary has been referred to as "The Master Gland" of body, or the "Chief Executive of Endocrine System", or "The Leader of Endocrine Orchestra"

Table : 5.7-6 Summary of the Principal Action of Anterior Pituitary Hormones








Hormone and Target Tissues	Principal Action	Hormone and Target Tissues	Principal Action
Human growth hormone (hGH) or somatotropin  Liver	Stimulates liver muscle cartilage, bone and other tissues to synthesize and secrete insulin like growth factor of body cells, protein synthesis, tissue repair, glucose concentration.	Prolactin (PRL)  Mammary glands	Together with other hormones, promotes milk secretion by the mammary glands.
Thyroid-stimulating hormone (TSH) or thyrotropin  Thyroid gland	Stimulates synthesis and secretion of thyroid hormones by thyroid gland.	Adrenocorticotrophic hormone (ACTH) or corticotropin  Adrenal cortex	Stimulates secretion of glucocorticoids (mainly cortisol) by adrenal cortex.
Follicle-stimulating hormone (FSH)  Ovaries      Testes	In females, initiates development of oocytes and induces ovarian secretion of oestrogens. In males stimulates testes to produce sperm.	Melanocyte-stimulating hormone (MSH)	Exact role in humans is unknown but may influence brain activity, when present in excess, can cause darkening of skin.

Table : 5.7-7 Summary of Posterior Pituitary Hormones

Hormone and Target Tissues	Control of Secretion	Principal Actions
<b>Oxytocin (OT)</b>  Uterus                      Mammary glands	Neurosecretory cells of hypothalamus secrete OT in response to uterine distention and stimulation of nipples.	Stimulates contraction of smooth muscle cells of uterus childbirth, stimulates contraction of myoepithelial cells in mammary glands to cause milk ejection.
<b>Antidiuretic hormone (ADH) or vasopressin</b>  Kidneys                      Sudoriferous (sweat) glands                      Arterioles	Neurosecretory cells of hypothalamus secrete ADH in response to elevated blood osmotic pressure, dehydration loss of blood volume, pain, or stress; low blood osmotic pressure, high blood volume, and alcohol inhibit ADH secretion	Conserves body water by decreasing urine volume; decreases water loss through perspiration; raises blood pressure by constricting arterioles.

## Hypothalamus

**Position and Structure :** Hypothalamus is the floor of diencephalon. It is formed of masses of grey matter, called hypothalamic nuclei, containing neurosecretory cells. It is connected with anterior pituitary lobe by blood capillaries of hypophyseal portal system and with the posterior pituitary lobe by axons of its neurons, both passing through the pituitary stalk.

**Hormones of hypothalamus :** Neurosecretory cells of hypothalamus secrete neurohormones called releasing factors (RF) or inhibiting factors (IF). These neurohormones are carried by hypophyseal portal system to adenohypophysis (primary target organ) and stimulate or inhibit the release of trophic hormones from adenohypophysis. These neurohormones are proteinaceous in nature and formed of 3 – 20 amino acids.

Table : 5.7-8 Neurohormones of Hypothalamus

S.No.	Neurohormones	Physiological effects
1	TRH (Thyroid Releasing Hormone Releasing Factor)	Increased TSH secretion from adenohypophysis
2	ACTH-RF (Adrenocorticotrophic Hormone-Releasing Factor)	Increased ACTH secretion from adenohypophysis
3.	STH-RF (Somatotrophic Hormone-Releasing Factor)	Increased STH secretion from adenohypophysis
4.	SOMATOSTATIN (GROWTH INHIBITING HORMONE)	Decreased STH secretion from adenohypophysis.
5.	GTH-RF (Gonadotrophic Hormone-Releasing Factor) (i) FSH-RF (Follicular Stimulating Hormone-Releasing Factor) (ii) LH-RH (In female) (Luteinising Hormone – Releasing Factor) or ICSH-RF (In male) (Interstitial Cells stimulating Hormone-Releasing Factor)	Increased FSH secretion from adenohypophysis.  Increased LH secretion from adenohypophysis.
6.	Prolactin-Releasing hormone (P-RH)	Increased secretion of prolactin or leuteotrophic hormone.
7.	Prolactin-Inhibiting hormone (P-IH)	Decreased secretion of prolactin or leuteotrophic hormone.
8.	MSH-RF (Melanophore Stimulating Hormone-Releasing Factor)	Increased MSH secretion from intermediate pituitary lobe.
9	MIF (Melanophore Inhibiting Factor)	Decreased MSH secretion from intermediate pituitary lobe.

**Hypothalamo – pituitary complex :** Pituitary gland is closely related with hypothalamus. Both together form hypothalamo-pituitary complex.

The hypothalamic-pituitary (hypothalamo-hypophyseal) system is a direct proof of coordination between the hormonal and nervous system. It regulates most of the physiological activities of body and maintains homeostasis inside the body. These neurosecretory cells are known to synthesize two more hormones : Oxytocin and Vasopressin, which are stored in their axons extending in the posterior lobe of pituitary gland.

## Thyroid gland

The name “thyroid” was introduced by Thomas Wharton (1656). It is derived from Greek “Thyreos” a shield.

**Location :** This is the largest endocrine gland of our body. It is located in our neck upon the ventral aspect of larynx (sound box or Adam's apple) and a few anteriormost tracheal rings. It is a dark brown and H-shaped/butterfly bilobed gland.

**Origin :** It is endodermal in origin and arises in the embryo as a midventral process from the floor of the tongue in pharyngeal region between the first and second pharyngeal pouches. Later, the duct-like connection (thyroglossal duct) of the process degenerates, so that the process is separated from the tongue and becomes endocrine. Probably, the gland is homologous to the endostyle of lower chordates

**Structure of thyroid gland :** In adult human beings, thyroid gland measures about 5 cm in length and 3 cm in width. Its average weight is 30 grams. It is somewhat larger in women. In old age, it becomes somewhat smaller as age advances. Its two lobes are connected by a narrower isthmus formed of nonglandular connective tissue. A small, conical pyramidal lobe is often found extended forwards from the isthmus. The whole gland is enveloped by a fibrous capsule. Thin septa or trabeculae, extending inwards from the capsule, divide the gland into a number of lobules. Each lobule, in turn, consists of a large number of small and hollow, spherical follicles (acini) embedded in a small amount of a loose connective tissue that forms the stroma of the gland.

The wall of each thyroid consists of a single-layered cuboidal epithelium suspended from a basal lamina, while its cavity is filled with a yellowish, jelly-like and iodinated colloid glycoprotein substance, called iodothyroglobulin. Besides containing a dense network of blood capillaries, the stroma contains small clusters of specialized parafollicular or 'C' cells. The latter are remnants of ultimobranchial bodies derived from the fifth pharyngeal (branchial) pouches in the embryo.

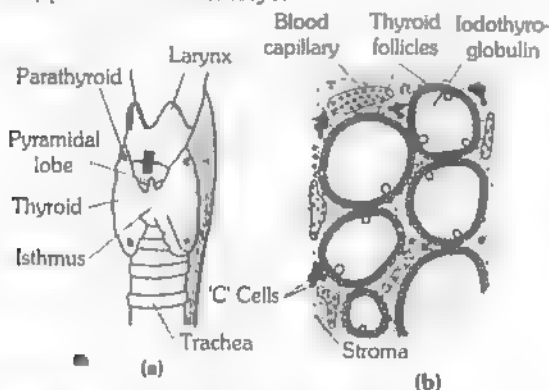


Fig : 5.7-10 (a) Thyroid gland, (b) Follicles suspended in stroma of a lobule

**Synthesis and storage of iodothyroglobulin :** Synthesis of a glycoprotein thyroglobulin (TGB) – occurs continuously in the follicular cells under genic control. The cells keep extruding thyroglobulin in follicular cavity by exocytosis. Each molecule of thyroglobulin contains about 500 amino acid monomers of which 123 monomers are of tyrosine at fixed places. Soon as the molecules of iodine and thyroglobulin come out of follicular cells, these interact in such a way that 15 tyrosine monomers of each thyroglobulin molecule at fixed places become iodinated. Certain tyrosine monomers bind with single atoms of iodine, forming monoiodotyrosine (MIT or  $T_1$ ). Other tyrosine monomers bind with two atoms of iodine, forming diiodotyrosine (DIT or  $T_2$ ). This is called organification of thyroglobulin. Molecules of iodothyroglobulin keep accumulating in follicular cavity, forming the jelly-like colloid. Within the colloid, molecules of iodothyroglobulin undergo conformational changes and may even

interact with each other. This results in a coupling of most of the iodinated tyrosine monomers in pairs. This coupling may occur between the iodinated tyrosine monomers of the same or different molecules of iodothyroglobulin. It results in the formation of several groups of complexes of tetraiodothyronine (thyroxine –  $T_4$ ) and some of triiodothyronine ( $T_3$ ) in the colloid. Each  $T_4$  complex obviously contains two tyrosine monomers and four atoms of iodine, whereas each triiodothyronine complex contain two tyrosine monomers and three atoms of iodine.  $T_4$  and  $T_3$  are actually the iodinated hormones secreted by thyroid. Obviously, the colloid acts as a reservoir of these hormones.

The daily output of thyroid glands is about  $80\mu\text{g}$  ( $0.08\text{mg}$ ) of  $T_4$  and about  $4\mu\text{g}$  of  $T_3$ . Since, however  $T_3$  is several times more potent, most of the  $T_4$  molecules also change into  $T_3$  molecules by losing one iodine atom as these diffuse from blood into ECF. This deiodination of  $T_4$  is maximum in the liver.

As described in a preceding account, the rate of thyroid secretion is controlled by pituitary gland and the hypothalamus of brain respectively under direct and indirect negative feedback regulation. Rate of thyroid secretion increases during winters and in pregnant women.

#### Synthesis and secretion of iodinated hormones

**Iodides and iodine :** An adult human body contains about 5 to 6 milligram of iodine and most of it is found in thyroid gland. Thus, the thyroid is a reservoir of iodine. For secreting the iodinated hormones in normal amounts, the thyroid daily utilizes about 150 micrograms ( $0.15$  milligram) of iodine. Obviously, a person must daily obtain  $150\mu\text{g}$  of iodine from food. We can obtain this from dairy products, drinking water, seafood, etc. If obtained more than this, we excrete the excess iodine in urine.

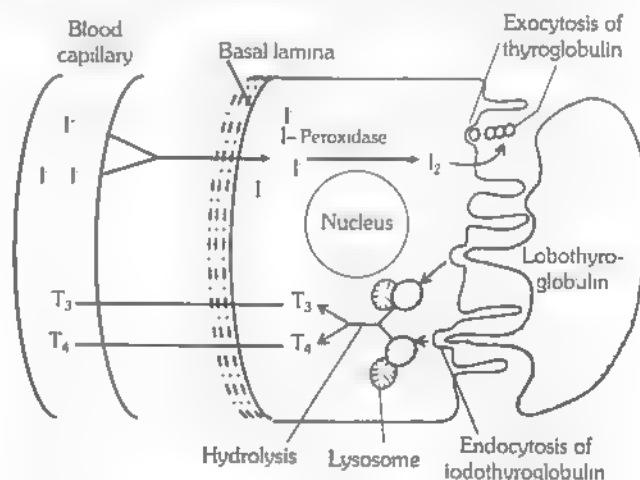


Fig : 5.7-11 Working mechanism of follicular cells of thyroid

Iodine of food is absorbed and circulated in blood in the form of iodide ions ( $I^-$ ). Follicular cells of thyroid very actively obtain these ions from blood by active transport. That is why, the concentration of  $I^-$  in these cells normally remains about 50 to 250 times more than in blood. These cells possess peroxidase enzyme in abundance. Peroxidase continuously oxidizes iodide ions into molecular iodine ( $2I^- \rightarrow I_2$ ). Iodine is, then, released by follicular cells into follicular cavity



### Hormones of thyroid

Thyroid gland secretes two iodinated hormones. Thyroxine ( $T_4$ ) and Tri iodothyronine ( $T_3$ ) and one non iodinated hormone thyrocalcitonin. Secretion of thyroid gland is regulated by TSH of anterior pituitary lobe. Thyroxine was first isolated by Kocher (1914) but was first crystalized by Kendall (1919). Its molecular structure was given by Harrington and Berger (1927). They also synthesized thyroxine.

(1) **Thyroxine** : It is an iodine containing (6% iodine) amine hormone which is derived from tyrosine amino acid. Chemically thyroxine is tetraiodothyronine though also found as tri-iodothyronine. Secretion of thyroxine is inversely proportional to the blood level of thyroxine (feed back mechanism). These hormones perform following functions -

(i) These regulate Basal Metabolic Rate (BMR) of the body as control rate of cell respiration and energy production in mitochondria hence the "Tempo. of life". So these control physical, mental and sexual growth of body. It is called calorogenic effect.

(ii) In 1912 Gudernatsch discovered that metamorphosis in frog's tadpole begins only when adequate amount of thyroxine is secreted by the thyroid of the tadpole. It was also found that hyposecretion of thyroxine retards and hypersecretion enhances the rate of metamorphosis.

In the hilly tracts of North America from whose soil all iodine has been washed away by rain water, the tadpoles of *Ambystoma* probably never metamorphose. Therefore, these tadpoles grow to a large size and attain sexual maturity, i.e., these become paedogenetic larvae. This phenomenon is called paedogenesis. The paedogenetic larvae of *Ambystoma* are called *Axolotl* larvae.

Addition of thyroxine or iodine in pond water naturally induces and enhances metamorphosis in the tadpoles.

(iii) Functions of osmo-regulation and regulation of moulting have been ascribed to these thyroid hormones in cold-blooded vertebrates (fishes, amphibians and reptiles).

(iv) These control working by renal tubules of kidney so control urine output.

(v) These help in homeothermy in warm blooded animals.

(vi) Synthesis of additional sodiumpotassium pump ( $Na^+/K^+$  ATPase), which then use more ATP more heat is given off, and body temperature rises. This phenomenon is called calorogenic effect of thyroid hormone, and thus maintain normal body temperature.

(2) **Thyrocalcitonin (TCT)** : It is a long peptide hormone secreted by parafollicular cells of thyroid gland (C-cells). Its secretion is regulated by increased plasma level of calcium by feedback mechanism. TCT lowers calcium level in blood to normal by increasing calcium deposition in the bones, so checks osteoporosis and stimulates excretion of calcium in urine. It prevent hypercalcaemia. Decreasing reabsorption of calcium from urine, so increasing excretion of  $Ca^{2+}$ . So it prevents hypercalcaemia.

### Irregularities of thyroid gland

(1) **Hypothyroidism** : (Decreased secretion of thyroxine from thyroid gland). It leads to the following diseases -

(i) **Cretinism** : It is disease of infants, called cretins. It is characterised by decreased BMR (50% than normal); stunted growth; retarded mental development so low I.Q., delayed puberty; decreased body temperature, heart rate, pulse rate, blood pressure and cardiac output; reduced urine output; decreased sugar level in blood, pigeon's chest (chest bulging forward in sternal region). Cretinism can be congenital (absence of thyroid due to genetic defect) or endemic (absence of iodine in diet). It can be corrected by thyroxine administration.

(ii) **Myxoedema** : It occurs due to deficiency of thyroxine in adults. Like cretinism, it also has low (BMR) (by 30 - 40%); low body temperature, reduced heart rate, pulse rate, blood pressure and cardiac output, low sugar and iodine level in blood etc. But the peculiar feature of myxoedema is that face and hands become swollen due to deposition of albuminous myxomatous tissue. It can also be corrected by thyroxine administration.

(iii) **Endemic or simple goitre or colloid goitre** : It occurs due to deficiency of iodine in drinking water. It is non-genetic (sporadic goitre is a genetic disease). It is characterized by enlargement of thyroid gland due to increase in number and size of acinar cells of thyroid gland. It is more common in people of hilly region. To prevent goitre, the table salt is being iodised these days.

(iv) **Hashimoto's disease** : It is called auto-immune thyroiditis and occurs due to age factor, injury-surgery, wrong treatment or infection of thyroid gland causing hyposecretion of thyroxine. When thyroxine secretion falls upto minimal limit, the antibodies are formed which destroy the thyroid gland.

(2) **Hypersecretion of thyroid hormones (Hyperthyroidism or thyrotoxicosis)** : This may also be a genetic defect, but usually it is provided by chronic infections (influenza, rheumatism, tonsillitis, tuberculosis, measles, whooping cough, etc.) pregnancy, intake of large doses of iodine, over-eating, etc. It results into a considerable increase in glucose and oxygen consumption by cells and the rate of oxidative metabolism in the mitochondria. Consequently, the BMR (basal metabolic rate) may increase several folds (hypermetabolism). The cells fail to store all catabolic energy into ATP. Consequently, the extra energy is liberated as heat. Instead of causing growth of body, this energy, thus, overheats the body, causing nervous tension and excitement, restlessness and anxiety, muscular weakness (thyrotoxic myopathy), fatigue and tremors, high temperature, palpitation of heart, copious sweating, diarrhoea, insomnia, trembling of limbs and body, weight loss, heat intolerance, warm and soft skin, increased appetite, etc.

Under his "Sodium pump theory of thermogenesis" Edelman has recently (1974) hypothesized that overheating of body in hyperthyroidism is not because cells fail to trap the excess catabolic energy in ATP, but because the excess ATP formed in this condition is utilized in considerably accelerating the  $Na^+-K^+$  pump, releasing more heat that overheats the body.

(i) **Simple goitre** : Hyperthyroidism may be simply because of overactive cells of a normal gland, or because of an enlargement of the gland, causing goitre.



(ii) **Exophthalmic goitre** : Such a goitre is called exophthalmic goitre, because it is usually accompanied with some asymmetrical protrusion (Exophthalmos) of the eyeballs, imparting an angry, frightened, or staring look to the patient. Protrusion of eyeballs is due to accumulation of mucus in eye orbits.

(iii) **Grave's or Basedow's disease** : Enlargement of the gland is usually due to a diffused growth

(iv) **Plummer's disease or Toxic Adenoma** : It is due to formation of one or more hypersecretory nodules.

## Parathyroid gland

(1) **Position and structure** : These are four in number which are wholly or partially embedded in the dorsal surface of the thyroid gland two glands in each lobe of thyroid gland. Each is oval shaped, small sized (5x5 mm) and yellow coloured. Histologically, a parathyroid gland is formed of two masses of polygonal cell arranged in cords. Endocrine cell are of two types principal or chief and oxyphil cells. Parathyroid is endodermal in origin.

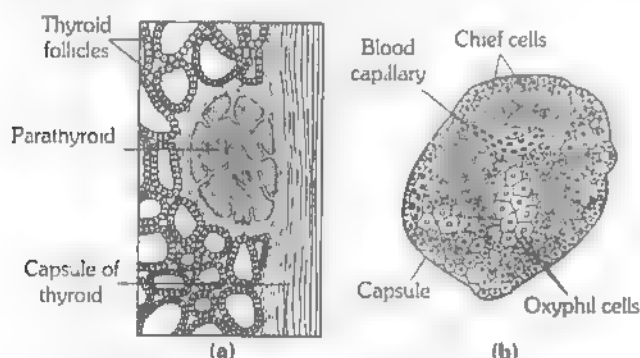


Fig : 5.7-12 (a) Parathyroid gland embedded in the surface of thyroid, (b) Ultrastructure of a parathyroid

(2) **Hormones of parathyroid** : Active hormone secreted by parathyroids is parathormone (PTH), also called Collip's Hormone (Phillips collip, 1925). It was discovered and purified by Collip in 1925. Its crystals were first prepared by Craig and Ras mussen in 1960. Its molecular structure was worked out by Potts and his associates in 1971. The latter is a protein of 84 amino acid monomer. It is a polypeptide hormone. Parathyroids are present in all vertebrates except fishes. Its secretion is stimulated by low level of calcium in blood than normal level through feedback control.

**Functions of parathormone** : Parathormone is essential for survival, because it significantly contributes to "homeostatis" by regulating the amount of calcium and phosphate ions in ECF. Parathormone maintains optimum level of plasma calcium by

- (i) Mobilisation from bones
- (ii) Reduced urinary excretion
- (iii) Increased absorption from intestine.

The level of phosphorus is not allowed to remain high by stimulating its urinary excretion. Our body requires an optimum calcium level (10.0 to 11.5 mg per 100 mL.) in ECF (total 1000 to 1120 grams in a 70 kg man), because calcium is a key element in many physiological functions like proper permeability of cell

membranes, muscular activities, nerve impulse conduction, heartbeat, blood coagulation, bone formation, fertilization of ova, etc. Calcium is most abundant of all minerals found in the body and about 99% of calcium and phosphorous are contained in the bones.

Maintenance of proper calcium level under 'homeostasis' is, in fact, a combined function of parathormone, thyrocalcitonin and vitamin D<sub>3</sub> (cholecalciferol). Parathormone promotes absorption of calcium from food in the intestine and its reabsorption from nephrons in the kidneys. Simultaneously, it accelerates elimination of phosphates in urine (phosphaturic action). Thus, calcium level tends to rise in the ECF due to the effect of parathormone. This calcium is, then, utilized by bone-forming cells – osteoblast – in bone formation under the influence of vitamin D<sub>3</sub>. Bones are asymmetrical when first formed. Their unnecessary parts are, therefore, dissolved by bone-eating cells called osteoclasts. This process also proceeds under the influence of parathormone. It results in release of calcium and phosphate in blood

Vitamin D<sub>3</sub> is a steroid hormone which is first synthesized in an inactive form in skin cells from 7-dehydrocholesterol under the influence of ultraviolet (UV) rays of sunlight. Skin cells release it in blood. Liver cells take it from blood, change it into 25-hydroxycholecalciferol and release back into blood. Finally, the cells of proximal convoluted tubules of nephrons in the kidneys change 25-hydroxycholecalciferol into 1-25-dihydroxycholecalciferol under the influence of parathormone. This last compound is released in blood as active vitamin D<sub>3</sub> named as cholecalciferol (calcitriol).

In addition to its role in bone-remodelling, D<sub>3</sub> also stimulates absorption of Ca<sup>2+</sup> and Mg<sup>2+</sup> in intestine. Similarly, parathormone also plays an additional role of stimulating excretion of Na<sup>+</sup>, K<sup>+</sup> and HCO<sub>3</sub><sup>-</sup>, but retarding the excretion of Mg<sup>2+</sup>.

## Irregularities of parathormones

### (1) Hypoparathyroidism (Hyposecretion of parathormone)

(i) It is rare, however, in undersecretion of parathormone, the level of calcium in ECF falls (hypocalcemia), and that of phosphates rises (hyperphosphatemia). This causes neuromuscular hyperexcitability, excessive perspiration, gooseflesh (raising of hairs and prickly sensation in skin), cooling of hands and feet, painful muscular spasms and convulsions, and trembling.

(ii) Sometimes some skeletal muscles, usually of hands and feet, fail to relax after a contraction, and remain in "sustained contraction". This is called "Tetany". Tetany of laryngeal, thoracic, and phrenic muscles, which help in breathing, causes death, because the patient fails to breathe (asphyxia).

(iii) Childhood hypoparathyroidism retards growth, particularly of bones, teeth, hair and brain. Vitamin D is administered to such children.

### (2) Hyperparathyroidism (Hypersecretion of parathormone)

(i) **Osteoporosis** : Oversecretion of parathormone is rare and occurs usually due to overgrowth of one or more parathyroid glands. It causes demineralization of bones which, therefore, become soft, weak, distorted and fragile. This is called osteoporosis.

(ii) **Hypercalcemia** : Simultaneously, due to a sharp rise in calcium level in blood and ECF (hypercalcemia) and a sharp fall in phosphate level (hypophosphatemia), muscles and nerves are weakened.

(iii) **Hypercalciurea** : Calcium is excreted in urine (hypercalciurea), thirst increases owing to copious urination, appetite is lost, constipation and headache become common, and often, kidney stones are formed. The only treatment so far known is removal of extra part of the glands by operation.

**Feedback control of secretion of parathormone and thyrocalcitonin** : Secretion of these two hormones is continuously regulated by a direct negative feedback. As  $\text{Ca}^{2+}$  levels tends to fall, secretion of parathormone increases, but that of thyrocalcitonin decreases. Contrarily, the secretion of parathormone decreases and that of thyrocalcitonin increases when  $\text{Ca}^{2+}$  level tends to rise in blood.

## Adrenal gland

Adrenal gland was first reported by Eustachius.

**Origin and position** : The adrenals are paired glands placed on the top or superior of the kidneys as cap. Hence, they are also called suprarenal glands

Adrenals have a dual origin, they are originated from ectoderm and mesoderm both. Like thyroid, adrenals are also highly vascular in nature.

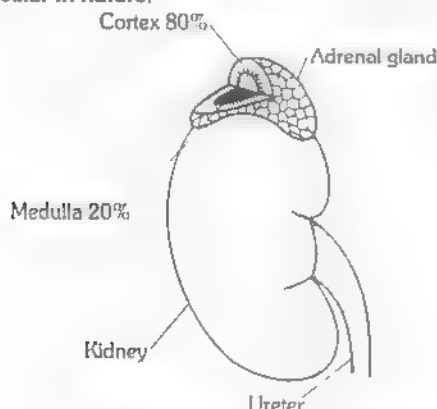


Fig : 5.7-13 Adrenal gland with a part cut to show cortex and medulla

**Structure** : Each adrenal is a small ( 5 cm long, 3 cm broad and 1 cm thick), triangular and yellowish cap like structure. Its weight in humans is about 3.5 to 5.09 gm. At birth adrenal glands are best developed. Each gland has two parts – outer cortex and inner medulla.

(1) **Outer cortex** : The cortex is derived from mesoderm and forms about 80% part of the gland. Cortex consists of fatty, cholesterol rich cells. These cells distinguish the cortex into three zones or regions.

(i) **Zona glomerulosa** : It is the outer part of the cortex (15% of the gland), which consists of small polyhedral cells. It secretes mineralocorticoids e.g., Aldosterone.

(ii) **Zona fasciculata** : It is the middle part of the cortex (50% of the gland). Which consists of large polyhedral cells. This part secretes gluco-corticoids. e.g., Cortison, Corticosterone.

(iii) **Zona Reticularis** : It is the inner part of the cortex (7% of the gland). In which the parallel cell cords of the zona fasciculata branched to form a loose anastomosing network. It secrets sex hormones.

(2) **Inner medulla** : The medulla is derived from ectoderm and forms about 20% part of the gland. Adrenal medulla is reddish brown in colour and colourless of rounded groups of short cords of relatively large and granular cells. These cells are modified postganglionic cells of sympathetic nervous system. These are called chromaffin cells or phaeochromocytes. Adrenal medulla secrets adrenalin and nor-adrenalin which are collectively called as catecholamines.

## Hormones of adrenal cortex

About 20 steroids (steroidogenic) compounds are secreted from adrenal cortex. These are called adrenocorticoids (corticosteroids). Only few of them are biologically active as hormone. These hormones are steroid in nature. The later, however account about 80% of the secretion of adrenal cortex and are classified into three categories.

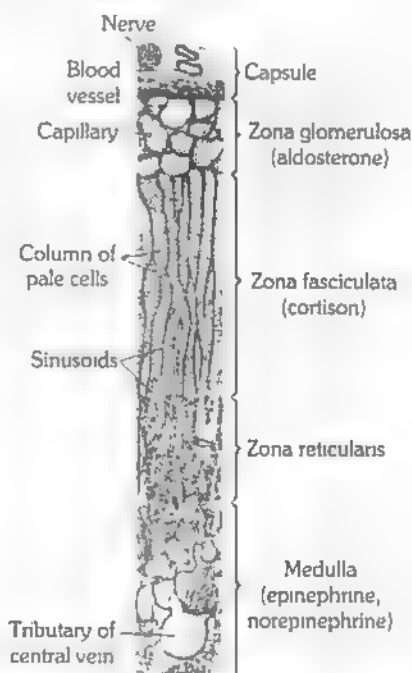


Fig : 5.7-14 Adrenal gland with a part cut to show cortex and medulla

(1) **Mineralo-corticoids** : The principal mineralocorticoid is aldosterone. It is also called salt-retaining hormone. It promotes reabsorption of sodium ions from kidney and excretion of potassium ions in urine. It also reabsorb  $\text{Cl}^-$  ions from kidney. Thus aldosterone has a important contribution in homeostasis by controlling osmotic pressure of ECF (Extra cellular fluid).

Remember that doctors administer saline drip to the patients who lose excessive water and salts due to diarrhoea, cholera, etc. Aldosterone also helps in maintaining acid-base equilibrium and blood pH (7.35) by promoting reabsorption of  $\text{HCO}_3^-$  and regulating excretion of  $\text{H}^+$  by kidneys. It also promotes absorption of water and salt in intestine, mainly in colon. The Renin-angiotensin-aldosterone or RAA pathway controls secretion of Aldosterone.

(2) **Glucocorticoids** : These include three main hormones – cortisol, corticosterone and cortisone. Cortisol is most abundant (about 95%) and most important. These hormones play an important role in carbohydrate, fat and protein metabolism as follows –

(i) Cortisol retards glucose consumption and protein synthesis, but promotes breakdown of proteins and fats in the cells.

(ii) Effects of glucocorticoids upon liver are anabolic. These promote intake of glucose, FFAs and amino acids by cells of liver. Then, these intensify deamination of amino acids, synthesis of urea, synthesis of glucose from fatty acids and amino acids (gluconeogenesis), and synthesis of glycogen from glucose (glycogenesis) in liver cells.

(iii) Cortisol is anti-inflammatory. It retards the migratory movements and phagocytic activities of white blood corpuscles (WBCs), suppressing "inflammation reactions" which constitute the normal defense mechanism of body against toxic substances. Simultaneously, it reduces the number of mast cells, reducing secretion of histamine. This is also an anti-inflammatory effect. It also denotes synthesis of collagen fibres which usually form at the sites of inflammation in normal defense. That is why, cortisol is usually injected as a drug for treatment of diseases that are caused by deposition of collagen fibres, such as arthritis or rheumatism.

(iv) Cortisol is also "immunosuppressive". It suppresses synthesis of antibodies, retarding the normal immune reactions of body against antigens and attack of micro-organisms. In fact, it induces atrophy of thymus gland and other lymphoid tissues, so that the productions of lymphocytes is inhibited. That is why, it is used for treatment of allergy. Also, it is used in transplantation surgery to suppress the formation of antibodies in the body of recipients so that the latter may accept the transplanted organs.

(v) Cortisol increases RBC count, but decreases the WBC count of blood. It also elevates blood pressure (BP).

(3) **Sex hormones** : The zona reticularis of adrenal cortex secretes androgen and estrogen in small quantity. These hormones regulate the development of sex organs, secondary sexual characters and promote growth and protein metabolism.

**Role of adrenal cortex in stress reaction** : Adrenal glands provide the body with an emergent "chemical defence mechanism" in stress conditions that threaten the physical integrity and chemical consistency of the body. After the "Fight or Flight" reaction, the body remains in a state of shock for some time just like a country after a war. Heartbeat, cardiac output, blood pressure and glucose and salt concentrations in ECF considerably go down in this "shock condition". For example, excessive bleeding in an accidental injury immediately sends the body into shock condition. The injured must be made to recline and his / her legs must be elevated by putting a few pillows under the feet and hips. This increases venous flow of blood towards the heart, so that the cardiac output is maintained.

Whereas the hormones of adrenal medulla elevate  $O_2$ -consumption, BMR, respiration and tension to increase alertness and responsivity to prepare the body for violent stress-reactions, those of adrenal cortex, particularly aldosterone and cortisol, serve to maintain the body in living condition and recoup it from the

severe after-effects of stress reactions. An increased output of cortisol is actually "life-saving" in shock conditions. It inhibits the normal defence mechanisms and mobilises help from all parts of the body in order to keep the body alive.

Adrenal glands are large in fetus, but these mainly secrete sex hormones. By the time of child-birth, these become small and their secretions remain minimal for a few days after birth. Obviously, the "chemical defence system" is very weak in newly born infants. The latter can, therefore, easily succumb to stress conditions. That is why, infants are provided extra care in maternity homes.

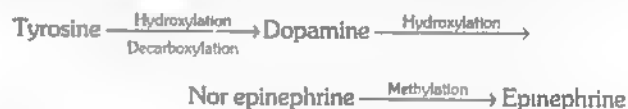
As is clear from above account, adrenal cortex is very necessary for survival, but adrenal medulla is not so necessary, because its deficiency can be compensated by sympathetic nervous system.

**Control of adrenal cortex secretions** : Secretion of glucocorticoids and sex hormones by adrenal cortex is regulated by a hormone, corticotropin or adrenocorticotrophic hormone (ACTH), secreted by the anterior lobe of pituitary gland. Secretion of ACTH from pituitary is, in turn, regulated by a "corticotropin-release hormone (ACTHRH)" of hypothalamus. A "feedback control mechanism" operates between hypothalamus, pituitary and adrenal cortex. A decrease in cortisol level in blood stimulates the hypothalamus and pituitary. Hence secretion of ACTHRH from hypothalamus and of ACTH from pituitary and, therefore, of glucocorticoids and sex hormones from adrenal cortex increases. When cortisol level in the blood rises, the control mechanism operates in reverse direction. This "feedback control" is very efficient and quick.

Secretion of mineralocorticoids is only nominally under the control of ACTH. Although adrenal glands themselves regulate secretion of mineralocorticoids according to  $Na^+$ , water and  $K^+$  levels in ECF, by feedback, but this regulation is mainly provided by the kidneys. As the blood pressure goes down due to decreased amount of salt and water in blood, certain cells of afferent arterioles that supply glomeruli secrete an enzyme named renin.

#### Hormones of adrenal medulla

The chromaffin cells of adrenal medulla synthesize two hormones adrenalin or epinephrine (80%) and nor-adrenalin or nor-epinephrine (20%). These hormones are proteinaceous in nature and derived from amino acid tyrosine. Which is first hydroxylated and decarboxylated to form dopamine and then the latter is hydroxylated again to finally form norepinephrine. Epinephrine is derived by methylation of norepinephrine.



Cortisol from adrenal cortex induce synthesis of enzymes needed to convert nor epinephrine to epinephrine. Norepinephrine lacks the converting enzymes. Because the ANS controls the chromaffin cells directly, hormones release can occur very quickly.

The molecular structure of dopamine, norepinephrine and epinephrine, includes a 6-carbon ring connected to two hydroxyl groups ( $-OH$ ). This is called catechol ring, and these compounds are called catecholamines for this reason.

Epinephrine (adrenalin) was first extracted by Abel (1899) who coined this name for it. It was, however, extracted in pure form by Jokichi and Takamine (1900). Its molecular structure was worked out by Aldrich in 1901. Stolz (1904) and Dakin (1905) synthesized it in their laboratories. Norepinephrine was discovered by Ulf von Euler (1946). Effects of these hormones were studied by Axelrod (1965). For their discoveries Euler and Axelrod won Nobel Prize in 1970.

#### Function of epinephrine

(1) Epinephrine causes constriction of the blood vessels (vasoconstriction) which supply blood to those peripheral and abdominal organs (skin and organs of digestive, excretory and reproductive systems) that normally remain active while we are resting or sleeping. Obviously, the activities of these organs are retarded, but the blood pressure (BP) increases.

(2) Reduced supply of blood causes a pale skin (pallor), but arrector pili muscles of skin contract, causing gooseflesh.

(3) Mouth becomes dry due to poor secretion of saliva.

(4) Food digestion is retarded because of reduced gut peristalsis due to relaxation of the smooth muscles of gut wall, as well as, because of poor secretion of digestive glands.

(5) Kidneys produce small volume of urine, and muscles or urinary bladder relax.

(6) In pregnant women, the muscles of uterus contract, increasing the possibility of abortion.

(7) Epinephrine causes dilation of blood vessels (vasodilation) which supply brain, skeletal muscles, heart, lungs, liver, adipose tissues, sensory organs, etc. Due to increased blood supply, these organs become very active, inducing alarm reaction. Obviously, the blood pressure, increased due to effect of norepinephrine, is reduced to some extent.

(8) Pupils dilate due to contraction of radial dilatory muscles of iris. Secretion of tear by lacrimal glands increases.

(9) Epinephrine causes relaxation of the smooth muscles of trachea, bronchi and bronchioles. These organs, therefore dilate, so that breathing becomes easier and faster. Remember that epinephrine is used in treatment of asthma for this reason.

(10) Contractions of cardiac muscles intensify, increasing both rate and force of heartbeat, pulse rate, arterial pressure and cardiac output

(11) Due to an increase in adhesiveness of blood platelets, the time of blood clotting is considerably reduced.

(12) The spleen contracts, releasing its reserve of blood corpuscles whose number in blood, therefore, increases.

(13) In islets of Langerhans in pancreas, secretion of insulin hormone decreases, but that of glucagon increases. Glucagon causes glycogenolysis, i.e. breakdown of glycogen into glucose in liver and skeletal muscles.

(14) Because of an increase in blood levels of  $O_2$ , glucose, FFA, etc the basal metabolic rate of all body cells considerably increases and renders the whole body highly active and irritable.

(15) External genitalia become flaccid, but ejaculation becomes early and forceful.

Since the rate and force of the activities of most internal organs increase in a few seconds under the effects of epinephrine and norepinephrine, the various changes can be detected by a lie detector polygraph to ascertain the emotional state of a person.

**Table : 5.7-9 Difference between Adrenal cortex and Adrenal medulla**

S.No.	Adrenal cortex	Adrenal medulla
1.	It is external firm region of the adrenal gland.	It is central soft region of the adrenal gland
2.	It is pale yellowish-pink in colour.	It is dark reddish-brown in colour.
3.	It is enclosed by a fibrous capsule.	It is not enclosed by a fibrous capsule
4.	It forms about 80% of the adrenal gland	It forms just 20% of the adrenal gland.
5.	It develops from the mesoderm.	It develops from the ectoderm (neural crests).
6.	It consists of 3 concentric regions : Outer zona glomerulosa, middle zona fasciculata and inner zona reticularis	It is not differentiated into regions
7.	It is essential for life, its destruction causes death.	It is not essential for life, its destruction does not cause death.
8.	It secretes 3 groups of hormones mineralocorticoids, glucocorticoids and gonadocorticoids	It secretes 2 similar hormones nor adrenaline and adrenaline.
9.	It is stimulated to release its hormones by the adrenocorticotrophic hormone from the anterior pituitary	It is stimulated to secrete its hormones by nerve impulses reaching via sympathetic nerve fibres
10.	There is no cooperation between adrenal cortex and sympathetic nervous system	Adrenal medulla and sympathetic nervous system function as an integrated system called sympathicoadrenal system
11.	It causes many deficiency / excess disorders	It is not known to cause any disorder

#### Significance of adrenal medullary hormones

**Relationship between adrenal medulla and sympathetic nervous system :** Our routine in voluntary activities like food digestion, respiration, heartbeat and blood circulation, thermoregulation, peristalsis of tubular organs, secretion of glands, excretion, etc are continuously and automatically done by our internal (visceral) organs without the conscious control of our brain. These are, therefore, called involuntary activities, these activities occur under the control of autonomic nervous system and their co-ordinated regulation is controlled by the hypothalamus of brain. The autonomic nervous system controls these activities by affecting the activity levels of

cardiac muscles, smooth muscles of visceral organs and blood vessels, and the glands. The autonomic nervous system comprises two control systems, having antagonistic effects of these organs. These are sympathetic and parasympathetic systems. Obviously, the motor nerve fibres of both these systems, originating from central nervous system (CNS), innervate most of the internal organs. The motor fibres of parasympathetic system stimulate those organs which remain more active while we are at rest or sleeping contrarily, the motor fibres of sympathetic system stimulate those organs which remain more active when we are awake and doing work.

The fibres of sympathetic system, innervating the organs, the postganglionic motor fibres. At their terminals, these release norepinephrine, a neurotransmitter which triggers an alteration in the activities of concerned organs. The adrenal medulla is also innervated by fibres of sympathetic system, but these are preganglionic fibres of this system. At their terminals these fibres release acetylcholine which stimulates chromaffin cells to release their hormones – epinephrine and norepinephrine. Circulating in blood, these hormones reach into the internal organs and not only increase the effects of sympathetic stimulation, but also prolong these effects about ten-fold. That is why, the sympathetic system and adrenal medulla are collectively considered as sympathoadrenal system, and the hormones of adrenal medulla are called sympathomimetic amines. Besides this, the medullary hormones, especially epinephrine, increase the basal metabolic rate (BMR) of all body cells, increasing the activity and irritability level of whole body. Since, however, the effects of sympathetic system and adrenal medullary hormones are complementary, a retarded efficiency of any one of these is compensated by the other.

Modern scientists have discovered that cells resembling chromaffin cells occur in small groups near the thoracic and abdominal ganglia of sympathetic system. These groups have been named paraganglia.

**Alarm or stress reaction :** Physico-chemical changes continuously occur in the external and internal environments of our body during our daily routine life, and our body keeps on maintaining homeostasis and functional equilibrium by counteracting the effects of these changes by alterations and co-ordinated regulations of the activities of various organs by sympathetic system under hypothalamic control. However, the emergency or stress conditions such as fear, anger, intense pain, accident and injury, burning, intense cooling or heating of body, sudden invasion of micro-organisms, poisoning, emotional upsets due to insult, restlessness, mental tension, anxiety, exertion, surgery, etc tend to disturb homeostasis and functional equilibrium to such an extent that the very survival of body is endangered.

As the sensory impulses of such strong stimuli called stressors, reach the brain, directly or through spinal cord, motor impulses or required responses are issued by hypothalamus to all organs, including adrenal medulla through the spinal cord. Consequently, norepinephrine is released simultaneously in all organs by sympathetic fibres, and a large amount of both epinephrine and norepinephrine is poured into blood by adrenal medulla. This

"mass release" of these hormones prepares the whole body, within seconds, for a violent physical reaction called alarm or stress reaction, and often referred to as general adaptation syndrome (GAS). In this reaction, the concerned person either boldly faces the emergency, or tries somehow to escape from it. That is why, it is called "Fight or Flight reaction".

### Effects of irregularities of adrenal secretion

(1) **Hyposecretion :** This may be a genetic defect. Undersecretion of adrenocorticoids (hypocorticism) causes Addison's disease which is relatively rare and occurs in both men and women between the ages of 20 to 40 years. This disease was first described by Thomas Addison in 1849, 1855. It is maintained in following symptoms :

(i) Owing to low aldosterone and gluco-corticoides level in blood, considerable amount of sodium ions and water is excreted in urine, leading to dehydration, low blood pressure, and weakness, all symptoms of a peculiar, Addisonian anaemia which is different from common pernicious anaemia resulting from entirely different causes like diarrhoea, cholera, etc.

(ii) Owing to low cortisol level, glucose level also falls in blood (hypoglycemia). This sharply reduces BMR in body cells. Due to hypoglycemia and hyperkalemia (increased  $K^+$  level in blood) efficiency of brain, liver, skeletal and cardiac muscles, etc declines. Body temperature also falls. Heartbeat may even stop, causing death.

(iii) Decreased cortisol level induces gastro-intestinal disorders, resulting in loss of appetite, nausea, vomiting, diarrhoea, abdominal pain and restlessness.

(iv) Due to a sharp decline in body's chemical defense and resistance, sensitivity to cold, heat, infection, poisoning and other adverse condition increases. Acute hypocorticism is catastrophic and threatens life. Complete destruction or removal of adrenals causes death in a short time, principally because of loss of excessive sodium in urine.

(v) Addison's disease also causes an increase in the number of WBCs, resulting into eosinophilia, lymphocytosis, leucocytosis, etc.

(vi) Undersecretion of sex hormones causes impotence in males and disorders of menstrual cycle in females.

(vii) Excessive deposits of melanin, particularly in the skin of open parts of body like face, hands, feet, neck, teats, etc cause deep bronzing of skin in these parts.

(viii) As increase in  $H^+$  concentration in blood may cause acidosis.

(2) **Hypersecretion :** Oversecretion of adrenocorticoids (hypercorticism) causes following disorders and diseases –

(i) Glucose level rises in blood (hyperglycemia). This may lead to diabetes mellitus.

(ii) Irregular deposits of fat, particularly in thoracic parts and face, imparts asymmetrical shape to the body. the face becomes red and rounded (moon face), shoulders swell (buffalo humps) and abdomen dilates and often shows lines of stretching. All these are

symptoms of Cushing's disease (Cushing, 1932). Patients may die from brain haemorrhage, cardiac arrest, pneumonia, etc.

iii) Retention of sodium and water is the ECF increases blood pressure, causing severe hypertension and associated symptoms like severe headache

iv) Excessive loss of potassium in urine causes potassium deficiency (hypokalemia). This leads to muscular weakness and convulsions and nervous disorders, and may even cause tetany and paralysis, copious and frequent urination (polyuria) and thirst, bed urination (nocturia), etc. Similarly, excessive loss of  $H^+$  in urine may cause alkalosis.



Fig : 5.7-15 A girl showing pseudohermaphroditism

(v) Excessive mobilization of materials from all parts of body had widespread deteriorating effects. For instance, mobilization of proteins from all cells causes tissue wasting. similarly, mobilization from bones renders the bones weak and fragile (osteoporosis).

(3) Excessive secretion of male hormones (androgens) in a female fetus before complete formation of ovaries results into pseudohermaphroditism due to masculinization of external genitals, and causes abnormal development of muscles, hair on face (beard and moustache), early sexual maturation, hoarse voice and absence of menstruation. The clitoris grows to penis size, while vagina and uterus remain underdeveloped. This is known as adrenogenital syndrome. The resultant females are sterile. Oversecretion of androgens after complete formation of ovaries and fallopian tubes causes only a moderate enlargement of clitoris. Oversecretion of androgens in girls after birth causes a gradual masculinization manifested in overgrowth of clitoris, under development of mammary glands and uterus and disturbed menstruation. Oversecretion of androgens in male children causes excessive development of penis (marcogenitosomia) and other secondary sexual organs and characteristics, but atrophy of testes so that there is no spermatogenesis. Early erections are noted. Due to the anabolic effects of androgens, both in girls and boys, growth is accelerated, muscles are well-developed and strong, and bones mature early.

(4) Excessive secretion of female hormones in adult males cause enlarged mammary glands (gynaecomastia) and retards growth of beard. Contrarily, excessive secretion of androgens in females in masculinizing and causes hirsutism (increased facial and body hair and muscle growth, clitoral enlargement, etc.)

## Pancreas

**Location and origin :** Pancreas (Gr. pankreas = sweet bread; Fr., pan = all + kreas = flesh) is a flattened and pinkish mixed gland (both exocrine and endocrine) situated in the concavity formed by duodenum just behind the stomach. It measures about 15 cm in length and 4 to 5 cm in breadth. It forms by fusion of two bilateral endodermal processes of embryonic intestine (duodenum of future adult).

**Structure :** About 99% part of the gland is exocrine and formed of hollow pancreatic acini or lobules embedded in a connective tissue stroma. In the stroma, there are numerous (approximately 1 to 2 million in human pancreas) small (0.1 to 0.2 mm in diameter) clusters of endocrine cells, called islets of Langerhans after the name of their discoverer, Paul Langerhans (1869).

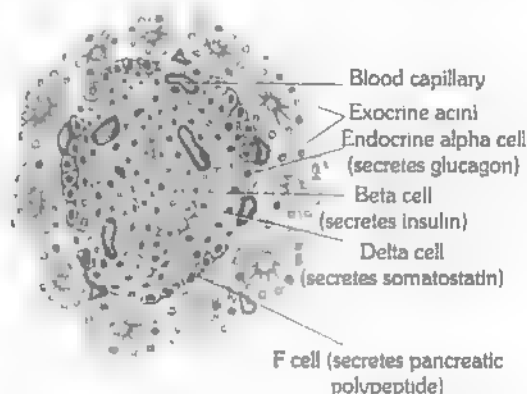


Fig : 5.7-16 T.S. of pancreas

### Cells Types in the Pancreatic Islets

Each pancreatic islet includes four types of hormone-secreting cells :

(1) **Alpha or A cells** constitute about 15% of pancreatic islet cells and secrete glucagon.

(2) **Beta or B cells** constitute about 80% of pancreatic islet cells and secrete insulin.

(3) **Delta or D cells** : It's constitute about 5% of pancreatic islet cells and secrete somatostatin (identical to growth hormone-inhibiting hormone secreted by the hypothalamus).

(4) **F cells** : It's constitute the remainder of pancreatic islet cells and secrete **pancreatic polypeptide**

### Hormones of pancreas and their role

The  $\beta$  and  $\alpha$  cells of islets of Langerhans respectively secrete insulin and glucagon hormones which are important regulation of carbohydrate, protein and fat metabolism in the body.

(1) **Insulin** : In 1889, Minkowski and Mehring discovered that pancreas is related with the disease of diabetes mellitus in humans. Normal concentration of glucose in blood is about 100 mg (0.1 gm) per 100 ml. It increases somewhat after a

carbohydrate rich food. Then, the secretion of insulin increases. It increases the permeability of all cells for glucose several times, except that of brain cells and red blood corpuscles (RBCs). The brain cells and RBCs are already highly permeable to glucose. After taking more glucose from blood, the cells utilize it for energy-production. Consequently, the basal metabolic rate (BMR) and RNA and protein synthesis increases in cells.

In 1923, two Canadian scientists, Banting and Best succeeded in preparing a pure extract of insulin from the pancreatic islets of a new born calf with the help of Macleod. Banting and Macleod won the 1923 Nobel prize for this work. Later, Abel (1926) succeeded in preparing pure crystals of insulin. F. Sanger (1955) worked out the molecular structure of bovine insulin and won the 1958 Nobel Prize. He discovered that insulin is a small protein whose molecule consists of two polypeptide chains,  $\alpha$  and  $\beta$ , joined by disulphide linkages and respectively formed of 21 and 30 amino acid residues. Insulin is the first protein to be crystallized in pure form, first protein whose molecular structure was worked out, the first protein to be synthesized in laboratory in 1964, and also the first protein to be commercially manufactured by means of DNA recombinant technique. Even the human insulin was also synthesized by Tsan in 1965.

(i) **Hypoinsulinism** : In insulin deficiency, body cells fail to obtain glucose from blood. Hence, glucose level of blood rises, a condition called hyperglycemia. When glucose level rises further, glucose starts passing out in urine. This condition is called glycosuria. Ultimately, when glucose level in blood rises to more than 200 mg/100 ml blood the person concerned suffers from diabetes mellitus in which the urine becomes sweet.

Diabetes mellitus has been known to Greeks as a human disease since 1500 B.C. In England, it was known as a "pissing evil" due to copious urination in it. Modern scientists have discovered that diabetes mellitus is of two types – I and II. The type I diabetes is usually found in young people, in some of which it is hereditary. About 10% of diabetic patients suffer from this type. Other patients suffer from diabetes of type II, usually found in people of over 40 years of age or obese persons. Diabetics excrete large volumes of urine. This is called polyuria. It results into dehydration which, in turn, causes increased thirst (polydipsia) and hunger (polyphagia). Being unable to utilize glucose for energy-production ("starving in midst of plenty"), the cells utilize their proteins for it, causing "body wasting". The body, therefore, becomes very weak. Nervous system may be damaged and often cataract occurs. Lipolysis in adipose tissues increases, elevating blood level of free fatty acids (FFA). Accelerated, but incomplete, oxidation of fatty acids for energy, especially in liver, results into the formation of ketone bodies – acetone, acetoacetic acid and  $\beta$ -hydroxybutyrate–, causing ketosis. Since the ketone bodies are sweet, acidic and poisonous, their increased amount in blood causes acidosis. Hence, patients may anytime become unconscious (coma condition) and finally die

Regular injections of insulin must be given to chronic patients of diabetes. Balanced diet, exercise, and regular intake of insulin tablets (eg dionyl) may keep diabetes in control. Certain drugs, like glyburide, which stimulate insulin secretion are now available.

(ii) **Hyperinsulinism** : Oversecretion of insulin enhances glucose intake by most body cells and glycogenesis in liver and muscles, causing a persistent decrease in blood glucose level (Hypoglycemia) since brain cells and cells of retina and germinal epithelium mainly depend on glucose for energy, nervous efficiency, fertility and vision sharply decline. Poor supply of glucose to the brain stimulates sympathetic nervous system, causing unnecessary excitement and feeling of anxiety, sweating, weakness, fatigue and muscular convulsions. Continued excess of insulin in blood causes "coma (insulin shock)" and death. Injections of cortisol, adrenaline, growth hormone and glucagon help in treatment of hyperinsulinism, because these hormones retard glucose utilization in cells and mobilize glucose and fatty acids respectively from liver and adipose tissues. Injections of glucose also give relief to the patients.

(2) **Glucagon** : This is secreted by the alpha cells of islets of Langerhans. It was discovered by Kimball and Murlin (1923). Like insulin, it is also a small protein. Its molecule consists of a single polypeptide chain of 29 amino acid residues. Its function is to elevate glucose level in blood when glucose is deficient. For this, glucagon intensifies glycogenolysis, deamination and gluconeogenesis, and inhibits glycogenesis in liver cells. It also intensifies lipolysis in adipose tissues. Thus, it is a promoter of catabolic metabolism. When, during excessive physical labour and stress, glucose consumption in the body increases and blood glucose level falls, glucagon is secreted to normalize the glucose level.

The secretion of insulin and glucagon is regulated by a "limit-control feedback" or "push and pull feedback" control system. When sugar level in blood increases, insulin is secreted and secretion of glucagon is inhibited. When, due to the effect of insulin, blood sugar level falls, secretion of insulin is inhibited and that of glucagon is stimulated.

(3) **Somatostatin and Pancreatic polypeptide** : Modern physiologists have postulated that the  $\delta$  and F (PP) cells of pancreas respectively secrete somatostatin (SS) and pancreatic polypeptide (PP). Somatostatin resembles the growth hormone inhibitory hormone (GHIH) secreted by hypothalamus. Its molecule is a small peptide of 14 amino acid residues. Acting as a paracrine hormone, it serves to retard secretory activities of  $\alpha$  and  $\beta$  cells. Besides this, it also slows down food digestion, absorption of digested nutrients and assimilation of nutrients in cells. Thus, it prolongs utilization of every feed. pancreatic polypeptide (PP) also acts as a local, paracrine hormone. It retards secretion of pancreatic enzymes and somatostatin. It also inhibits motility of stomach, duodenum and gall bladder.



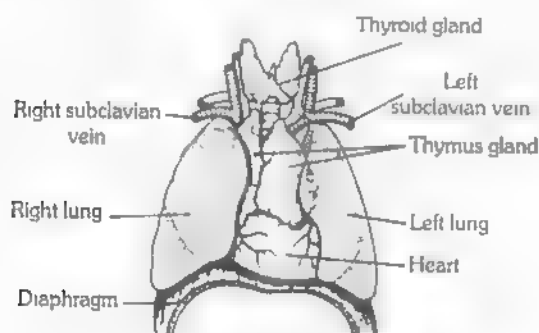
**Table : 5.7-10 Difference between diabetes mellitus and diabetes insipidus**

S.No.	Diabetes mellitus	Diabetes insipidus
1.	It is due to deficiency of insulin	It is due to deficiency of ADH.
2.	The blood sugar becomes high and glucose appears in urine	The blood glucose is normal and glucose does not appear in urine
3.	There is high blood cholesterol and ketone body formation.	There is no such phenomenon.

### Thymus gland

**Origin and position :** The thymus is a bilobed gland, located in the upper part of the thorax near the heart in the mediastinum. It is endodermal in origin, arising in the embryo from the epithelium of outer part of third branchial pouches.

**Structure :** Structurally, it is like a lymph gland enveloped by a thin, loose and fibrous connective tissue capsule. Septa, or trabeculae extending inwards from the capsule, divide the two lobes of the gland into a number of small lobules. Each lobule is distinguished into a cortical parenchyma containing numerous lymphocytes, and a medullary mass of large, irregularly branched and interconnected epithelial cells (reticular cells), a few lymphocytes and some phagocytic cells called macrophages or Hassall's corpuscles.

**Fig : 5.7-17 Location of thymus gland**

### Function of thymus glands

(1) Thymus is haemopoietic, as well as, an endocrine gland. Thymus is the "seedbed" of "thymic lymphocytes (T-lymphocytes). Certain "stem cells", originating in yolk sac and liver in early embryo, but only in bone marrow in late embryo, migrate into the thymus and proliferate to form a large number of lymphocytes.

(2) The major function of thymus is to secrete thymosin hormone, thymic humoral factor (THF), thymic factor (TF), thymopoietin. These compounds induce, not only the proliferation of lymphocytes, but also their differentiation into a variety of clones differently specialized to destroy different specific categories of antigens and pathogens likely to get into the body. This is called maturation of lymphocytes.

(3) As is clear from above account, thymus is essential in neonatal (newly born) infant and postnatal child for normal development of lymphoid organs and cellular immunity. That is

why, the thymus, small at birth, progressively grows in size about three or four-folds upto about the age of puberty. By this time lymphoid organs and tissues are well-developed. The thymus, therefore, starts gradually diminishing in size and its tissue is progressively infiltrated by yellowish adipose tissue. This is known as the "immunity theory of ageing". By the old age, the thymus is reduced to quite a thin, yet functional chord of tissue.

### Pineal gland (Epiphysis)

**Origin, position and structure :** This is a small, whitish and somewhat flattened ectodermal gland situated at the tip of a small, fibrous stalk that arises from dorsal wall of diencephalon, i.e. the roof (epithalamus) of third ventricle of the brain. Due to its location, it is also called epiphysis cerebri. It is covered over by a thin capsule formed of the pia mater of the brain. Septa from this membrane extend into the gland, dividing it into lobules having two types of branched cells, viz the large and modified nerve cells, called pinealocytes, and interstitial or neuroglial cells forming the supporting tissue. The pineal gland starts degenerating after the age of about 7 years because of deposition of granules of calcium salts (brain sand) in it.

**Function of pineal body :** Hormone, though the function of the gland is still the subject of current research, it is known to secrete one hormone, melatonin. Melatonin concentration in the blood appears to follow a diurnal (day-night) cycle as it arises in the evening and through the night and drops to a low around noon. Melatonin lightens skin colour in certain animals and regulates working of gonads (testes and ovaries). Light falling on the retina of the eye decreases melatonin production, darkness stimulates melatonin synthesis. Girls blind from birth attain puberty earlier than normal, apparently because there is no inhibitory effect of melatonin on ovarian function.

Serotonin, a neurotransmitter found in other locations in the brain, is also found in the pineal gland. Research evidence is accumulating to support the idea that the pineal gland may be involved in regulating cyclic phenomena in the body. Melatonin also is a potent antioxidant. Melatonin causes atrophy of gonads in several animals.

### Gonads

The gonads are the sex glands, the testes and the ovary. Testes is the male gonad and ovary is the female gonads. Besides producing gametes, the gonads secrete sex hormones from the onset of puberty (sexual maturity) to control the reproductive organs and sexual behaviour.

The sex hormone were discovered by Adolf Butenononol in 1929 and 1931. He won the 1939 Nobel prize jointly with Leopold Ruzicka

### Testes

**Location and structure :** In testes between the seminiferous tubules, special types of cells are present called interstitial cells or cells of Leydig. These cells secrete male hormones (androgens) derived from cholesterol. The main androgen is testosterone other less important androgens include androstenedione and



dehydroepiandrosterone (DHEA). It is a masculinizing hormone. From puberty to the age of about twenty year i.e. adolescence or the period of sexual maturation or attainment of adult hood.

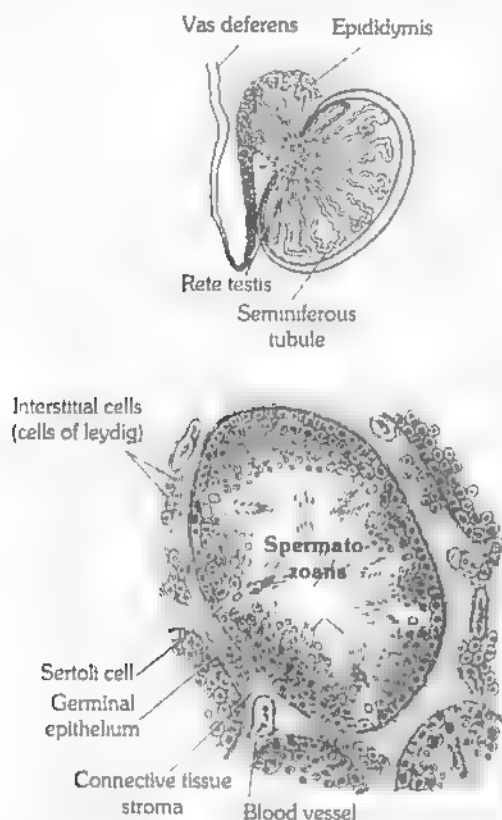


Fig : 5.7-18 Ultrastructure of testes

### Function

- (1) It stimulates the male reproductive system to grow to full size and become functional.
- (2) It stimulates the formation of sperms (spermatogenesis) in the seminiferous tubules.
- (3) It stimulates the development of male accessory sex characters such as hair on the face (beard and moustaches), growth and distribution of hair on the body, thickening of skin, deepening of voice, enlargement of larynx, broadening of shoulders, narrow lips enlarged and stronger bones and muscles. It also maintains these characters.
- (4) It also determines the male sexual behaviour sexual urge, aggressive behaviour.
- (5) Under its effect protein anabolism increases. (This function is obvious in the heavier muscle and bone mass of most men as compared to women).
- (6) Grythropoiesis in bone marrow increases.
- (7) In brief, testosterone determines libido or sex drive. It is also required, together with the follicle stimulating hormone (FSH) of pituitary, for initiation and completion of spermatogenesis. All androgens are also secreted in traces from adrenal glands in both boys and girls.
- (8) Increased sebaceous gland secretion.

**Development of testis :** Under the effect of chorionic gonadotropic hormone, secreted by placenta during pregnancy, the testes of eight to nine months old fetus start secreting testosterone. The latter regulates differentiation and development of urinogenital system, accessory genital organs and external genitalia in the embryo. During childhood i.e. from birth to puberty (age of 11 to 13 years), testes remain quiescent, so that androgens are not secreted. At puberty, the gonadotropic hormones (FSH and ICSH) of pituitary reactivate the testes which, therefore, start producing sperms and resume secreting androgens. Up to the age of about 40 years, androgens are secreted in sufficient amounts. Thereafter, their secretion starts gradually declining, but the capability of reproduction still continues for many years.

**Castration :** Surgical removal of testes is called castration or orchidectomy. Castration, or deficient secretion of testosterone (hypogonadism) before puberty (due to congenital defects or injury to testes) retards growth of genitalia, muscles and bones, as well as, the development of sexual characteristics.

Castration or hypogonadism after puberty preserves the libido, but diminishes its overall efficiency (demasculinization). Muscular strength, hair growth, spermatogenesis, sex urge and potency sharply decline. Sometimes, the person becomes impotent.

Castration is widely used in animal husbandry and domestication. Castrated cattle, horses and fowls are respectively called steers, geldings and capons. Castration makes these docile.

### Ovary

Primordial ovarian follicles are formed in the primitive ovaries of female fetuses as early as about 16 weeks of gestation, but these do not secrete hormones. Even in early childhood, up to the age of 7 or 8 years, ovaries remain quiescent. Thereafter, the pituitary starts secreting gonadotropins (FSH and LH) under whose influence puberty in girls sets in at about the age of 11 to 13 years; ovaries become active and menstrual cycle begins, so that the girls attain sexual maturity. Reproductive period, i.e., ovarian function and menstrual cycles in women normally cease at about the age of 45 to 55 years. This is called menopause. It usually results in a rise in urinary excretion of gonadotropins of the pituitary gland.

**Ovarian hormone :** Under the influence of FSH and LH. They secrete three female sex hormone, estrogen, progesterone and relaxin. They are derived from cholesterol.

(1) **Oestrogen :** These are secreted by the cells of the Graffian (ovarian) follicle surrounding the maturing ovum in the ovary. They stimulate the female reproductive tract to grow to full size and become functional. They also stimulate the differentiation of ova (oogenesis) in the ovary. They also stimulate the development of accessory sex characters such as enlargement of breasts, broadening of pelvis; growth of pubic and axillary hair; deposition of fat in the thighs, and onset of menstruation cycle. Graffian follicle cells are stimulated to secrete oestrogens by luteinising hormone (LH) from the anterior lobe of the pituitary gland. Rise of blood-oestrogens level above normal inhibits the secretion of LH from the anterior pituitary. This negative feedback prevents the oversecretion of oestrogens.

(2) **Progesterone** : It is secreted by the corpus luteum. The latter is a yellowish body formed in the empty Graffian follicle after the release of the ovum. Its hormone suspends ovulation during pregnancy, fixes the foetus to the uterine wall, forms placenta, and controls the development of the foetus in the uterus. Progesterone is also called anti-abortion hormone. Ovulation, formation of corpus luteum and secretion of progesterone are stimulated by the luteinising hormone (LH) from the anterior pituitary.

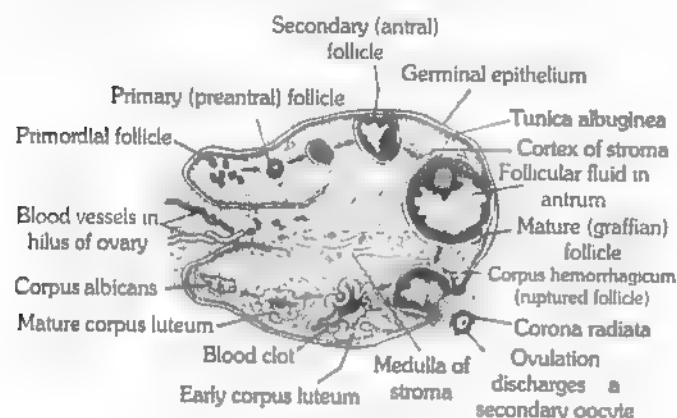


Fig : 5.7-19 V.L.S. of ovary

(3) **Relaxin** : It is produced by the corpus luteum at the end of the gestation period. It relaxes the cervix of the uterus and ligaments of the pelvic girdle for easy birth of the young one.

**Regulation of ovarian hormone** : Secretion of estrogens is regulated by the gonadotropins of pituitary. Undersecretion of estrogens (hypogonadism) before puberty due to congenital defects or damage to ovaries, causes female eunuchoidism. Accessory genitals and breasts remain underdeveloped, pelvis remains narrow and buttocks flat. Secondary sexual characteristics also do not develop. Hypogonadism in adulthood reduces fertility and disturbs menstrual cycles. Oversecretion (hypersecretion of hypergonadism) of estrogens also disturbs menstrual cycles and may even cause cancer.

**Gravidex test** : Involve testing of hcG of placenta in the urine to test the pregnancy.

**Contraceptive pills** : Contain less oestrogens and more progesterone so called combined pills. These check ovulation and so pregnancy in female.

**Adiposogenital syndrome** : Also called hypothalamic eunuchoidism characterized by hypogonadism in male caused by genetic inability of hypothalamus to secrete gonadotrophin releasing hormones.

### Hormonal Contraception

**Female contraception** : As already described, gonads are stimulated to produce sex cells (gametes) and secrete sex hormones by the gonadotropic hormones (FSH and LH) of anterior pituitary. The anterior pituitary is, in turn, stimulated to secrete gonadotropins by the gonadotropin-releasing hormone

(GnRH) of hypothalamus. In women, FSH promotes oogenesis and secretion of female hormones (estrogens). LH promotes ovulation, formation of corpus luteum and secretion of progesterone from it. A negative feedback regulation operates between GnRH and gonadotropins, on one hand, and between gonadotropins and female hormones on the other. Hence, high concentration of female hormones retards secretion of FSH, LH and GnRH due to which oogenesis does not occur, and pregnancy is out of question. Contraceptive pills of mixtures of estrogens and progesterone are more effective. The most popular contraceptive pills contain synthetic ethinyl estradiol and synthetic progesterone (e.g. norethindrone). In a modern method, a capsule of synthetic progesterone, like levonor gestrel, is implanted under the skin. The capsule serves for contraception for about five years.

Abortion is also now permissible in many countries to check population growth. Since progesterone is necessary to maintain early pregnancy, drugs, like mifepristone (RU-486), which inhibit the effects of progesterone are administered for abortion.

**Male contraception** : In men, LH stimulates cells of Leydig to secrete male hormones (androgens) of which testosterone is the principal hormone. Testosterone, in turn, inhibits LH secretion, but not FSH secretion by anterior pituitary. FSH and testosterone stimulate spermatogenesis. It has been found that large doses of testosterone can inhibit secretion of gonadotropin-releasing hormone (GnRH) by thalamic cells, thereby inhibiting secretion of both LH and FSH by pituitary. Hence systematically administered injections of testosterone have been suggested as a means of male contraception.

Recently, the cells of Sertoli in seminiferous have been found to secrete a protein factor named inhibin which directly inhibits secretion of FSH by pituitary. Hence, use of inhibin as a male contraceptive is now being explored.

### Gastro-intestinal mucosa, placenta, skin, kidney and heart

(1) **Gastro-intestinal mucosa** : Inner most layer of the wall of the alimentary canal is called mucosa. Certain cell of the mucosa of the stomach and intestine secrete important hormones. Gastro-intestinal mucosa is endodermal in origin.

(i) **Stomach** : The mucosa of the pyloric stomach near the duodenum secretes a hormone called gastrin. Presence of food in the stomach provides a stimulus for gastrin secretion. Gastrin stimulates the gastric glands to produce the gastric juice. It also stimulates the stomach movements.

(ii) **Intestine** : The intestinal mucosa secretes six hormones : secretin, cholecystokinin, enterogastrone, enterocrinin, duocrinin and villikinin. Entry of acidic food from the stomach into the duodenum serves as a stimulus for the release of these hormones.

(a) **Secretin** : It is produced by the small intestinal mucosa. It causes the release of sodium bicarbonate solution from the pancreas for pancreatic juice and from the liver for bile. It also inhibits the secretion and movements of stomach.

(b) **Cholecystokinin-pancreozymin (CCK-PZ)** : This hormone is secreted by the mucosa of entire small intestine. The actions of cholecystokinin and pancreozymin were discovered independently. But it has been discovered that both hormones have similar effects and hence it is considered one hormone. As the name suggest CCK-PZ has two main functions. The word cholecystokinin is derived from three roots : Chol meaning bile, Cyst meaning bladder, and kinin meaning to remove. The word pancreozymin is derived from pancreas and Zym, which means enzyme producer. This hormone stimulates the gall bladder to release the bile and also stimulates the pancreas to release its enzymes.

(c) **Enterogastrone** : It is secreted by the duodenal mucosa. It shows gastric contractions and stops the secretion of gastric juice.

(d) **Enterocrinin** : It is secreted by duodenal mucosa. It stimulates crypts of Lieberkuhn to secrete the enzymes in the intestinal juice.

(e) **Duocrinin** : It is secreted by the duodenal mucosa. It stimulates the release of viscous mucus from Brunner's glands into the intestinal juice.

(f) **Villikinin** : It is secreted by the mucosa of the entire small intestine. It accelerates the movements of villi to quicken absorption of food.

(2) **Placenta** : When the early embryo reaches into the uterus from fallopian tube, it becomes implanted with uterine wall by a placenta for support and nutrition. The cells of placenta secrete two steroid hormones (estradiol and progesterone) and two protein hormones (human chorionic gonadotropin-hCG and human chorionic somatomammotrophin-HCS). Early placenta secretes so much of chorionic gonadotropin that the latter starts being excreted in mother's urine just after about two weeks of pregnancy. Its presence in urine is used for pregnancy test. It serves to maintain the corpus luteum, and to stimulate it for secretion. Due to its effect, the corpus luteum continues secreting oestrogens, progesterone and relaxin. It also serves to maintain pregnancy by preventing contraction of uterine wall. After about three months of pregnancy, secretion of progesterone by the placenta increases. Hence, importance of corpus luteum decreases, and it starts degenerating. If therefore, ovaries are surgically removed at this stage, pregnancy remains unaffected, i.e. there is no abortion and the fetus grows and develops normally

The chorionic somatomammotropin was formerly known as placental lactogen. Reaching into mother's body, it serves as a mid growth hormone and promote growth of milk glands.

**Relaxin hormone** : This hormone has been obtained from corpus luteum of ovaries and from the placenta. It is a polypeptide.

During pregnancy it causes relaxation of the ligaments of pubic symphysis, and towards the termination of pregnancy, softens and widens the opening (cervix) of uterus for easy child birth (parturition). A temporary structure with endocrine function is placenta.

(3) **Skin** : Vitamins of D group are synthesized in skin cells under the effect of ultraviolet (UV) rays of sunlight from cholesterol-derived compounds. Cholecalciferol ( $D_3$ ) is the main D vitamin. It circulates in blood. Liver cells convert it into hydroxycholecalciferol (calcidiol) by hydroxylation and release back into blood. Certain cells of proximal convoluted tubules of nephrons in the kidneys convert calcidiol into dihydroxycalciferol (calcitriol) by further hydroxylation and release back into blood. Calcitriol is an important regulator of  $Ca^{2+}$  homeostasis. It promotes absorption of  $Ca^{2+}$  and phosphorus in intestine and bone-formation. It is therefore, required for growth of body and bone healing. Its deficiency in childhood causes thin, weak and curved bones, a condition called rickets. Its deficiency after growth period, causes weak, porous and fragile bones. This is called osteomalacia.

(4) **Kidney** : Whenever the rate of ultrafiltration in kidneys decreases due to low blood pressure (BP), the cells of juxtaglomerular complexes secrete into blood a compound named renin. The latter is a proteolytic enzyme. It acts upon a large plasma-protein formed in liver and called angiotensinogen, separating a small protein from it called angiotensin-I. Besides their function of excretion, the kidneys secrete three hormones, viz calcitriol, renin and erythropoietin. Calcitriol is the active form of vitamin  $D_3$  as already described. While the blood flows in blood capillaries of liver, an angiotensin-converting enzyme (ACE) converts angiotensin-I into angiotensin-II which acts as a hormone. This hormone accelerates heartbeat and constricts arterioles increasing blood pressure. Consequently, the rate of ultrafiltration increases. Simultaneously, it stimulates adrenal cortex to secrete aldosterone, and enhances water and sodium reabsorption from nephrons. These factors also increase the volume of ECF, elevating blood pressure.

Erythropoietin (EPO) controls formation of erythrocytes (red blood corpuscles-RBC's) in red bone marrow. That is why, its secretion increases on decrease in blood volume, or RBC count, or haemoglobin deficiency (anaemia). Hence EPO is also called renal erythropoietic factor. Contrarily, its secretion decreases when RBC count tends to increase due to blood transfusion or other reasons.

(5) **Heart** : When volume of ECF and blood pressure (BP) increase due to retention of more NaCl in the body, certain cardiac muscle cells of the atria of heart secrete an atrial natriuretic peptide (ANP) which acts as a hormone. The effect of ANP is to promote copious urination (diuresis) and excretion of NaCl (natriuresis) to normalise ECF volume and BP. It also inhibits the effect of vasoconstrictor hormones and secretion of renin, aldosterone and vasopressin hormones.

Table : 5.7-11 List of hormones, their chemical nature and functions

S.No.	Name of endocrine gland	Name of hormone and its chemical nature	Functions
1	Neurosecretory cells of Hypothalamus (Supraoptic Nucleus and Paraventricular Nucleus)	Oxytocin and vasopressin mono peptide  Gonadotropin releasing hormones Other releasing hormones e.g. TSHRH, MSHRH, ACTHRH, GHRH etc. Proteinaceous	Milk ejection and parturition (oxytocic effect) Vasoconstriction and antidiuretic (vasotocin) effects. Stimulates FSH and LH synthesis Stimulate TSH, MSH, ACTH GH secretions from pituitary.
2	Pituitary (a) Neurohypophysis (Pars Nervosa) (b) Adenohypophysis (contains diverse cell types)	Store and release Oxytocin and Vasopressin  Proteinaceous or glycoprotein	Hormone release is related to physiological state and requirements. Affect growth, development differential pubertal changes and other metabolic mechanism.
3.	Pineal	Melatonin-derived from the amino acid tyrosine	Antagonist to FSH / LH Regulates biological / circadian rhythms.
4	Thyroid gland (amine hormone) having $-NH_2$ group)	(a) Thyroxine, iodinated amino acid called tyrosine ( $T_2$ , $T_3$ , $T_4$ ). (b) Thyrocalcitonin (Peptide)	(a) Controls basal metabolic rate (BMR) All organ, system of body responds to thyroxine. (b) Facilitates $Ca^{+2}$ absorption
5.	Parathyroid gland	Parathormone, Peptide	$Ca^{+2}$ and $PO_4$ metabolism
6	Thymus	Thymosine (polypeptide)	Anti FSH and LH, delays puberty
7.	Islets of Langerhans (= Endocrine pancreas) (i) $\alpha$ -cells (ii) $\beta$ -cells (iii) $\delta$ -cells	Glucagon Insulin Secretin Isolated by Banting Polypeptide	(i) Gluconeogenesis / Glycogenolysis (ii) Glycogenesis (iii) Gastric functions
8.	Adrenal gland (a) Adrenal medulla (Amine hormone have $-NH_2$ )  (b) Adrenal cortex	(a) Catecholamines (epinephrine = adrenaline, and norepinephrine = noradrenaline (derived from tyrosine) (b) Mineralocorticoids and glucocorticoids and traces of androgen and oestrogen steroids derived from cholesterol	Stresses = emergency = Fright, Fight and Flight Hormone (3F) accelerates cardiac functions muscle activity etc. (b) Electrolyte and carbohydrate metabolism
9.	Ovary (a) Granulosa cells steroid, fat soluble have sterol group derived from cholesterol (b) Corpus luteum  Placenta temporary endocrine gland formed during pregnancy	Oestrogen (Steroid) oestrone, oestradiol  Oestrogen and Progesterone (Steroid)  (a) Steroid secreted are estrogen and progesterone (b) Relaxin-Polypeptide	(a) Secondary sex character primary action on uterine endometrium mitogenic.  (a) Secreted during luteal phase of menstrual cycle in human female and oestrous cycle of other mammals. Prepares uterine endometrium for receiving blastocyst for implantation. Progesterone is also called pregnancy hormone and is anti-FSH and anti-LH/anti-LTH (a) Maintenance of pregnant state prevents lactogenesis folliculogenesis, and Ovulation. (b) Act on pubic symphysis and enlarges the birth canal to facilitate birth. Acts synergistically with oxytocin during this process (parturition)
10.	Testis (i) Sertoli cells (= sustentacular cells) (ii) Leydig cells (=Interstitial cells)	(i) Inhibin - Polypeptide (ii) Oestradiol Steroid Androgens (e.g. Testosterone) Steroid androstenedione)	Inhibits FHS action and attenuates spermatogenesis decrementally (i) Pubertal changes in male, (ii) Secondary sex characters in male, (iii) Sex drives, (iv) Spermatogenesis
11.	Gastro-intestinal hormones (secreted by cells of mucosa of stomach and intestine) also called hormones (a) Pyloric stomach (Argentophil cells) Intestine	Gastrin (i) Secretin (ii) Cholecystokinin (CCK) (iii) Enterogastrone (iv) Duocinin (v) Enterokinin (vi) Villikinin	Stimulates gastric juices secretion from gastric gland, movement of sphincters of stomach and increased movement of stomach (i) Stimulates secretion of succus entericus, (ii) Bile released from gall bladder, (iii) Inhibits gastric secretion, (iv) Stimulates secretion of mucous from Brunner's gland, (v) Stimulate intestinal gland, (vi) Stimulate villi movement

Table : 5.7-12 Disease caused by hormonal irregularities

Disease	Hormone	Quantity	Gland
Dwarfism	GH	Deficiency	Pituitary
Gigantism	GH	Excess	Pituitary
Acromegaly	GH	Excess	Pituitary
Simmond's disease	GH	Deficiency	Pituitary
Diabetes insipidus	ADH	Deficiency	Pituitary
Cretinism	Thyroxine	Deficiency	Thyroid
Simple goitre	Thyroxine	Deficiency	Thyroid
Myxoedema	Thyroxine	Deficiency	Thyroid
Exophthalmic goitre	Thyroxine	Excess	Thyroid
Tetani	Parathormone	Deficiency	Parathyroid
Plummer's disease	Thyroxine	Excess	Thyroid
Addison's disease	Mineralocorticoids (Aldosterone) and Glucocorticoids (cortisol)	Deficiency	Adrenal cortex
Conn's disease	Mineralocorticoids	Excess	Adrenal cortex
Cushing's disease	Corticosteroid	Excess	Adrenal cortex

## Local hormones, pheromones and insect endocrine glands

### Local hormones

Hormones described so far are called circulating hormones, because these circulate in whole body with blood. When stimulated by physical or chemical stimuli, all body cells, except red blood corpuscles (RBCs), secrete certain such compounds which transmit coded informations of metabolic adjustments between neighbouring cells and hence remain ECF instead of diffusing into the blood. These compounds are called local tissue hormones or autocrine. These are short-lived, because various enzymes present in ECF continue degrading these at a fast rate.

Local hormones are of two main categories-paracrine and autocrine. Paracrine hormones affect metabolism of cells located in the neighbourhood of those which secrete them. Autocrine hormones affect metabolism of the every cells which secrete them. Most local hormones are paracrine. These belong to the following categories :

(1) **Eicosanoids** : These are a category of lipids derived from fatty acid, arachidonic acid, synthesized in the plasma membrane of cells, and released in ECF. These are of four categories, viz. Prostaglandins, prostacyclins, thromboxanes and leukotrienes.

(i) **Prostaglandins (PGs)** : In 1935, Ulf von Euler discovered that human semen contains a very active compound presumably secreted by prostate gland and, hence, named as such. He found that after the semen is discharged in woman's vagina, this compound contracts uterine muscles to facilitate the sperms to ascend into fallopian tubes and reach ova to fertilize these.

(ii) **Prostacyclins** : These are found in walls of blood vessels and induce vasodilation. These also facilitate flow of blood in vessels and prevent thrombosis by inhibiting aggregation of platelets.

(iii) **Thromboxanes** : These are secreted by blood platelets. These help in blood clotting by instigating aggregation of platelets

at the place of injury. These also instigate vasoconstriction at places of injury to prevent excessive loss of blood.

(iv) **Leukotrienes** : These are secreted by eosinophils of blood and mast cells of connective tissues. These serve as mediators in inflammatory and allergic reactions, induce bronchoconstriction (constriction of bronchioles), constrict arterioles and induce migration of neutrophils and eosinophils towards the places of inflammation. These can cause asthma, arthritis, colitis, etc.

(2) **Neuroregulators** : These are a category of proteins which function as paracrine hormones in nervous tissues. These can be classified in three categories as follows :

(i) **Neurotransmitters** : These are synthesized in nerve cells and are secreted by exocytosis by axon terminals of these cells. These serve to transmit nerve impulses from one neuron to other neighbouring neuron, or muscles, or glands across synapses. About 60 of these have so far been discovered, but the most common of these are acetylcholine, norepinephrine, dopamine, serotonin and histamine.

(ii) **Neuromodulators** : In nervous tissues, the neurons secrete such paracrine hormones which modulate (increase or decrease) the excitability of other neighbouring neurons. These hormones are called neuromodulators. The main positive neuromodulators which increase the excitability of other neurons are the amino acids glutamate and aspartate, and polypeptide named 'P' substance. Contrarily, the main negative modulators which decrease the excitability of neighbouring neurons are the amino acid glycine and gamma aminobutyric acid (GABA), polypeptides named enkephalins, endorphins, dynorphins and tachykinins, and the nitric oxide (NO).

(iii) **Nerve growth factors** : The supporting glial cells of nervous tissues and cells of muscles, salivary glands and many other tissues secrete such polypeptide paracrine hormones which play important role in growth, development and survival of nerve cells. That is why, these hormones are collectively called neurotrophins.

### Pheromones

These are defined as chemicals excreted or released by one animal to the exterior, but evoke a physiological or behavioral response in another animal of the same species. Some pheromones, release on body surface, evoke a response in the recipient when tasted by the latter by licking, but most pheromones are volatile and odorous fatty acids (hydrocarbons) whose air borne molecules are received by recipient animals through olfaction. Certain insect pheromones are well-known examples. For instance, certain insects secrete bombykol or gyplure to attract their mating partners. Some other insects release geranoil to transmit information of food, source of danger to their fellows.

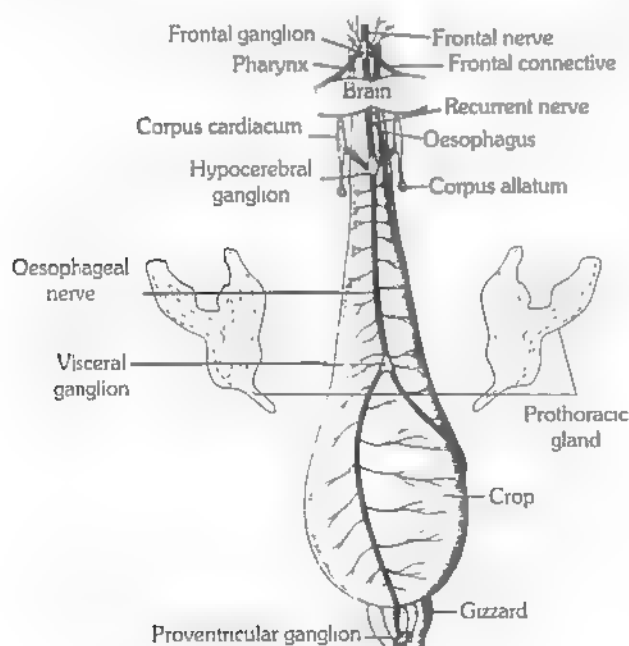
In mammals, presumably including humans, certain volatile fatty acids secreted in vaginal fluid by females acts as pheromones. These may evoke sex drive in males, or affect menstrual cycle in other females. It has been observed that there is a tendency of synchronized menstrual cycles in female roommates. This "dormitory effect" must be due to pheromones.

**Table : 5.7-13 Types of pheromones**

S.No.	Type	Example
1.	Sex pheromones	Bombycol – Silkmoth (female) Queen substance – Honey bee (Queen) Civetone – Cat Muskone – Muskdeer
2.	Aggregation pheromones	Geradiol – Honey bee
3.	Alarm pheromones	Danger signals
4.	Marking pheromones	Mark the territory in wild animals

### Insect endocrine glands

The endocrine system of cockroach comprises Intercerebral gland cells, corpora cardiaca, corpora allata, and prothoracic glands.



**Fig : 5.7-20 Endocrine glands of cockroach**

(1) **Intercerebral gland cells** : These cells lie in the brain between the two cerebral ganglia. They secrete a hormone called the brain hormone. This hormone activates the prothoracic glands to secrete their hormone.

(2) **Corpora cardiaca** : These are a pair of rod-like bodies situated on the sides of the oesophagus just behind the brain. They secrete a growth hormone.

(3) **Corpora Allata** : These are a pair of small, rounded bodies lying close behind the corpora cardiaca. They secrete a juvenile hormone in the nymphal stages. This hormone causes retention of the nymphal characters and checks the appearance of adult characters. In other words, it keep the insect young. In the last nymphal form, corpora allata become inactive, thereby resulting in the absence of juvenile hormone. The absence of this hormone permits the appearance of adult features. In the adult, the corpora allata again become active and secrete a gonadotropic hormone, which regulates egg production and development and functioning of the accessory sex glands.

(4) **Prothoracic glands** : These are fairly large, irregular glands situated in the prothorax. They secrete a hormone called ecdyson, which controls moulting of the nymphs. The prothoracic glands degenerate after metamorphosis.

## Tips & Tricks

✍ The word 'endocrine' is derived from a Greek word meaning 'I separate within'.

✍ The word 'hormone' was first used in reference to secretin.

✍ The father of endocrinology is Thomas Addison. The first endocrine disease reported was Addison's disease (1855) caused by the destruction of adrenal cortex or glucocorticoids.

✍ When two hormones work against each other to control a process, this is called antagonism, e.g., Insulin and Glucagon, Calcitonin and Parathormone.

✍ There are some hormone – like substances, but not the products of endocrine glands. They are parahormones, e.g., Prostaglandins and Pheromones.

✍ Hormones are not present in food but are synthesized in body.

✍ Protein hormones act at membrane level and change the permeability of plasma membrane.

✍ Steroid hormones enter nucleus and inactivate or activate the function of some gene.

✍ Although thyroxine is not a steroid hormone but it is lipid soluble and acts at gene level like steroid hormones.

✍ Water soluble hormones act through extracellular receptors.

- ✎ Lipid soluble hormones act through intracellular receptors.
- ✎ Insulin receptor is a heterotetrameric protein consisting of  $2\alpha$  subunits and  $2\beta$  subunits.
- ✎ One signaling molecules activates many mediators and one molecule of mediator activates hundreds of other molecules. In this way a signal is amplified hundred folds.
- ✎ Hormones secreted at nerve endings are called neurohormones or neurohumors.
- ✎ Sutherland received Noble prize in 1971 for his contribution in field of understanding of mechanism of hormone action.
- ✎ Secondary messengers are intermediate compounds that amplify a hormonal signal.
- ✎ By using two opposite signals within a cell sympathetic and parasympathetic nervous system achieve opposite actions.
- ✎ Cells have receptors for insulin and glucagons which also have antagonistic effects.
- ✎ Although thyroxine is not a steroid hormone but it is lipid soluble and acts at gene level like steroid hormones.
- ✎ Endocrine glands with ducts are pancreas, ovaries and testes.
- ✎ Primary target organ of hypothalamus is pituitary gland.
- ✎ In amphibians and reptiles pineal gland is considered third vestigial eye.
- ✎ In human pituitary, the intermediate lobe is functional in embryo but is rudimentary in adult.
- ✎ One neuron-one hormone hypothesis is followed by pituitary cells.
- ✎ Growth hormone is the only hormone of anterior pituitary that has direct effect on body cells
- ✎ Median eminence is a part of posterior pituitary.
- ✎ Myasthenia gravis : Abnormal neuromuscular excitation due to hypersecretion of thyroxine.
- ✎ Hormones are also called autocoids or chemical messengers or information molecules.
- ✎ Local hormones are also called para-hormones or tissue hormones.
- ✎ First discovered hormone was secretin but first isolated hormone was insulin and was isolated from pancreas of dogs by Banting and McLeod.
- ✎ Thyroxine hormone is derived from tyrosine amino acid while oxytocin and ADH are short chain peptide hormones
- ✎ Pheromones : These are intra-specific chemical messengers released by an animal into air to initiate specific response in another animal of same species. These may be signals of food, mate etc. These are also called ectohormones. Term pheromone was coined by Karlson and Butendant (1959).
- ✎ **Feedback inhibition** : In this, end product sends certain inhibitory signals (called negative feedback) when end product is at required level.
- ✎ **Endocrinologist** : Scientist involved in the study of endocrine glands.
- ✎ **Ecdysone** : A steroid hormone secreted by prothoracic glands present in the prothorax of insects the cockroach and controls moulting or ecdysis.
- ✎ **Corpora cardiaca** : A part of rod-like endocrine glands found in insects on the sides of oesophagus and secrete growth hormone which controls the growth of nymphs.
- ✎ **Juvenile hormone** : Secreted by a pair of rounded endocrine glands called corpora allata, present just behind corpora cardiaca. These secrete juvenile hormone in the nymphal stage and checks the appearance of adult characters.
- ✎ Level of hormones in our blood can be measured by Radio Immune Assay (RIA).
- ✎ Hormone receptors are always proteinous and are located either on cell membrane of target cells or in cytosol.
- ✎ Spleen does not secrete any hormone.
- ✎ Basal metabolic rate (BMR) – minimum energy required during rest or sleep (160 Kcal/day)
- ✎ Thyroid gland is only endocrine gland that stores its secretory product.
- ✎ During continuous stress size of adrenal gland (mainly adrenal cortex) increases.
- ✎ Human insulin was prepared for the first time by Tsan in 1965
- ✎ Insulin is effective only when it is given by injection.
- ✎ If insulin is taken orally, it is digested.
- ✎ Chemicals, alloxan and streptozotocin selectively destroy beta cells of islets of Langerhans
- ✎ Cobalt chloride selectively destroys alpha cells of islets of Langerhans.
- ✎ **Humulin** : Genetically engineered human insulin is called humulin
- ✎ **Acidosis** : Decrease in pH of blood e.g. in diabetes mellitus.
- ✎ The seminal vesicles are the chief source of prostaglandins in semen
- ✎ The commonest prostaglandins are  $PGA_1$ ,  $PGA_2$ ,  $PGE_1$ ,  $PGE_2$ ,  $PGF$ .

# Ordinary Thinking

## Objective Questions

### Hormones and their mechanism

- The name second messenger is given to  
[NCERT; MP PMT 2002]  
Or  
In the mechanism of action of a protein hormone, one of the second messengers is [NCERT]  
(a) ATP (b) Cyclic AMP  
(c) GTP (d) Both ATP and AMP
- In mechanism of hormone action, which of the following is not a second messenger [MHCET 2015]  
(a) Cyclic AMP (b)  $IP_3$   
(c)  $Ca^{++}$  (d)  $Mg^{++}$
- What is hormone [MP PMT 1998]  
(a) Glandular secretion  
(b) Enzyme  
(c) Chemical messenger  
(d) Organic complex substance
- ... shows anti-allergic and anti-inflammatory effect [GUJCET 2015]  
(a) Mineralocorticoids (b) Glucocorticoids  
(c) Sex corticoids (d) Noradrenaline
- Which is the inhibitory hormone of GH [GUJCET 2015]  
(a) Insulin (b) Parathormone  
(c) Somatostatin (d) Testosterone
- The chemical nature of hormones secreted by  $\alpha$  &  $\beta$  cells of pancreas is [WB JEE 2009]  
(a) Glycolipid (b) Glycoprotein  
(c) Steroid (d) Polypeptide
- Which of the following cell does not secrete hormone [MP PMT 2000]  
(a) Kupffer cell  
(b) Leydig cell  
(c) Lutein cell  
(d) Para follicular cells of thyroid
- Which of the following hormones are produced in the hypothalamus and stored in the posterior pituitary [KCET 2006]  
(a) FSH and LH (b) ADH and oxytocin  
(c) TSH and STH (d) ACTH and MSH
- Which of the following is not necessarily a property of all hormones [AIIMS 1993]  
(a) Information carrying (b) Secreted in low amounts  
(c) Short half-life (d) Protein in nature
- The feed back control mechanism is related with [CBSE PMT 2000; BHU 2002]  
(a) Bile secretion (b) HCl secretion  
(c) Hormonal secretion (d) Hering breuer reflex
- Pheromone is [MP PMT 2000]  
(a) A product of endocrine gland  
(b) Used for animal communication  
(c) Messenger RNA  
(d) Always protein

- Consider the given diagrammatic representation of the mechanism of action for 2 categories of hormones. In which of the following option correct answers for blanks A to I are indicated [NCERT]



Figure - I

Biochemical Responses

Physiological Responses

Figure - I

Cell membrane

D



Figure - II

- A - Steroid hormone, B - Enzyme, C - Secondary messenger, D - Non- steroid hormone, E - Nucleus, F - Hormone - enzyme complex, G - Genome, H - mRNA, I - protein
  - A - Steroid hormone, B - Receptor, C - Primary messenger, D - Non- steroid hormone, E - Nucleus, F - Hormone- receptor complex, G - Genome, H - mRNA, I - protein
  - A - Non -Steroid hormone, B - Receptor, C - Secondary messenger, D - Steroid hormone, E - Nucleus, F - Hormone receptor complex, G - Genome, H - mRNA, I - Protein
  - A - Steroid hormone, B - Receptor, C - Secondary messenger, D - Non- steroid hormone, E - Nucleus, F - Hormone - receptor complex, G - Genome, H - mRNA, I - protein
- Who is the "Father of Endocrinology" [CPMT 2000; BHU 2006]  
(a) Whittaker (b) Einthoven  
(c) Pasteur (d) T. Addison
  - Term 'hormone' was coined by [CPMT 1994]  
(a) W. M. Bayliss (b) E. H. Schally  
(c) E. H. Starling (d) G. W. Harris



15. Receptors for protein hormones are located  
(a) In cytoplasm (b) On cell surface  
(c) In nucleus (d) On endoplasmic reticulum
16. Which one of the following flows directly into blood from the seat of its production to act on an organ away from it  
(a) Enzyme (b) Hormone (Renin)  
(c) Blood (d) Lymph
17. Which is not involved as 2<sup>nd</sup> messenger in  $Ca^{+2}$  mediated hormone [NCERT; DPMT 2007]  
(a) c-AMP (b) DAG  
(c) Phospholipase (d)  $IP_3$
18. Hormones may be [BVP 2003; CBSE PMT 2004]  
(a) Amino acid derivatives (b) Peptides  
(c) Steroids (d) All the above
19. Which of the following statements is correct in relation to the endocrine system [NEET 2013]  
(a) Releasing and inhibitory hormones are produced by the pituitary gland  
(b) Adenohypophysis is under direct neural regulation of the hypothalamus  
(c) Organs in the body like gastrointestinal tract, heart, kidney and liver do not produce any hormones  
(d) Non-nutrient chemicals produced by the body in trace amount that act as intercellular messenger are known as hormones
20. Endocrine glands [NCERT; J & K CET 2002; Odisha JEE 2012]  
(a) Do not possess ducts  
(b) Sometimes do not have ducts  
(c) Pour their secretion into blood through ducts  
(d) Always have ducts
21. According to the accepted concept of hormone action, if receptor molecules are removed from target organs [CBSE PMT 1995; AFMC 1999]  
(a) The target organ will continue to respond to the hormone without any difference  
(b) The target organ will continue to respond to the hormone but will require higher concentration  
(c) The target organ will not respond to the hormone  
(d) The target organ will continue to respond to the hormone but in the opposite way
22. All functions of the body are regulated and integrated by [MP PMT 1994, 96]  
(a) Respiratory system (b) Digestive system  
(c) Neuroendocrine system (d) Excretory system
3. What is correct to say about the hormone action in humans [CBSE PMT (Pre.) 2012]  
(a) Glucagon is secreted by  $\beta$ -cells of Islets of Langerhans and stimulates glycogenolysis  
(b) Secretion of thymosins is stimulated with aging  
(c) In females, FSH first binds with specific receptors on ovarian cell membrane  
(d) FSH stimulates the secretion of estrogen and progesterone
4. Which is a 32 amino acid water soluble peptide hormone [AMU (Med.) 2010]  
(a) Gastrin (b) Calcitonin  
(c) Glucagon (d) Insulin
5. A health disorder that results from the deficiency of thyroxine in adults and characterized by (i) a low metabolic rate, (ii) increase in body weight and (iii) tendency to retain water in tissues is [CBSE PMT 2009]

Or

Man with thick lips, dirt deposited on tongue, low heart beating rate, with excess amount of cholesterol in blood, is supposed to be suffering from which abnormality

[CPMT 1996]

- (a) Hypothyroidism (b) Simple goitre  
(c) Myxoedema (d) Cretinism
6. One of the following cells secretes a hormone [MHCET 2015]  
(a) Cells of Leydig (b) Cells of Sertoli  
(c) Primary spermatocyte (d) Secondary spermatocyte
7. Which one of the following hormones is not involved in sugar metabolism [AIPMT 2015]  
(a) Aldosterone (b) Insulin  
(c) Glucagon (d) Cortisone
8. The hormones of posterior pituitary are oxytocin and vasopressin; but later is better known as [CPMT 2009]  
(a) Antidiuretic hormone (b) Growth hormone  
(c) Corticotrophic hormone (d) Neurohypophyseal
9. Which one of the following four glands is correctly matched with the accompanying description [AIIMS 2008]  
(a) Thyroid – Hyperactivity in young children causes cretinism  
(b) Thymus – Starts undergoing atrophy after puberty  
(c) Parathyroid – Secretes parathormone, which promotes move-ment of calcium ions from blood into bones during classification  
(d) Pancreas – Delta cells of the islets of Langerhans secrete a hormone, which stimulates glycolysis in liver
10. The hormone that maintains the secretory activity of the corpus luteum as well as the increase in the size of the mammary glands is  
(a) Estrogen (b) Luteinizing  
(c) Luteotrophin (d) Gonadotrophin
11. Which one of the following pairs of organs includes only the endocrine glands [CBSE PMT 2008]  
(a) Thymus and Testes (b) Adrenal and Ovary  
(c) Parathyroid and Adrenal (d) Pancreas and parathyroid

### Different glands and their hormones

1. Select the mismatch pair from the following [KCET 2015]  
(a) Oxytocin – Contraction of uterine muscles  
(b) Insulin – Gluconeogenesis  
(c) Prolactin – Milk production in mammary glands  
(d) Glucagon – Glycogenolysis
2. Inadequate production of STH in early life may result in  
(a) Gigantism (b) Acromegaly  
(c) Sterility (d) Dwarfism

12. Secretion of the androgen by Leydig cells of testis is under the regulatory influence of [KCET 2004]  
 (a) LTH (b) FSH  
 (c) STH (d) ICSH
13. The process of spermatogenesis and sperm formation is under the regulatory influence of [CPMT 1994]  
 (a) FSH (b) ADH  
 (c) LH (d) LTH
14. In human adult females oxytocin [MH CET 2005; CBSE PMT 2008]  
 (a) Stimulates pituitary to secrete vasopressin  
 (b) Causes strong uterine contractions during parturition  
 (c) Is secreted by anterior pituitary  
 (d) Stimulates growth of mammary glands
15. Which hormone stops the release of FSH from the pituitary after fertilization [CMC Vellore 1993; MP PMT 2009]  
 (a) Placental hormone (b) Fertilizin  
 (c) Estradiol (d) Luteinizing hormone
16. Diabetes insipidus is caused due to the deficiency of [AIIMS 1993; MP PMT 1997, 2003; CPMT 1999]  
 (a) Oxytocin (b) Insulin  
 (c) Vasopressin (d) Glucagon
17. A person suffering from diabetes insipidus will pass what amount of urine per day [MP PMT 1993]  
 (a) 1 litre (b)  $\frac{1}{2}$  litre  
 (c) 3 litres (d) 1.5 litres
18. Which one of the following hormones through synthesized elsewhere is stored and released by the master gland [AIPMT 2015]  
 (a) Luteinizing hormone  
 (b) Prolactin  
 (c) Melanocyte stimulating hormone  
 (d) Antidiuretic hormone
19. The blood calcium level is lowered by the deficiency of [CBSE PMT 2008]

Or

The hormone that increases the blood calcium level and decreases its excretion by kidney is

[DUMET 2009; WB JEE 2011]

Or

Tetany (Irregular muscle contraction) and osteoporosis are caused due to the deficiency of [MP PMT 1999, 2001; JIPMER 2002; WB JEE 2011; Kerala PMT 2012]

- (a) Both calcitonin and parathormone  
 (b) Calcitonin  
 (c) Parathormone  
 (d) Thyroxine
20. The activity of adrenal cortex is governed by a pituitary hormone abbreviated as [DPMT 1993]  
 (a) HCG (b) FSH  
 (c) ACTH (d) TSH

Or

Addison's disease is caused by under secretion of [DPMT 1993]

21. Which one of the following pairs of hormones are the examples of those that can easily pass through the cell membrane of the target cell and bind to a receptor inside it (Mostly in the nucleus) [CBSE PMT (Pre.) 2012]  
 (a) Insulin, glucagon (b) Thyroxine, insulin  
 (c) Somatostatin, oxytocin (d) Cortisol, testosterone
22. The intermediate lobe of the pituitary gland produces a secretion which causes a dramatic darkening of the skin of many fishes, amphibians and reptiles. It is [CBSE PMT 1993; Pb. PMT 1999]

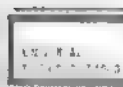
Or

Which of the following pituitary hormone is a direct action hormone [MP PMT 2003]

- (a) Adrenocorticotrophic hormone (ACTH)  
 (b) Follicle stimulating hormone (FSH)  
 (c) Melanocyte stimulating hormone (MSH)  
 (d) Luteinizing hormone (LH)
23. The Leydig cells as found in the human body are the secretory source of [NCERT; MH CET 2007; CBSE PMT (Pre.) 2012]  
 (a) Progesterone (b) Intestinal mucus  
 (c) Glucagon (d) Androgens
24. Serotonin and Melatonin are hormones, secreted by [MHCET 2015]  
 (a) Pancreas (b) Pineal body  
 (c) Pituitary gland (d) Thymus
25. Select the correct matching of a hormone, its source and function [CBSE PMT (Mains) 2010]

	Hormone	Source	Function
(a)	Vasopressin	Posterior Pituitary	Increases loss of water through urine
(b)	Norepinephrine	Adrenal medulla	Increases heart beat, rate of respiration and alertness
(c)	Glucagon	Beta-cells of Islets of langerhans	Stimulates glycogenolysis
(d)	Prolactin	Posterior Pituitary	Regulates growth of mammary glands and milk formation in females

26. Pineal gland of human brain secretes melatonin concerned with [RPMT 2005; MP PMT 2012; PET (Pharmacy) 2013]  
 (a) Anger (b) Body temperature  
 (c) Colouration of skin (d) Sleep
27. Endemic goiter is a state of [WB JEE 2010]  
 (a) Increased thyroid function  
 (b) Normal thyroid function  
 (c) Decreased thyroid function  
 (d) Moderate thyroid function



28. The anterior lobe of pituitary affects  
 (a) Protein metabolism  
 (b) Fat metabolism  
 (c) Carbohydrate metabolism  
 (d) All of the above
29. Complete failure of adenohypophysis of pituitary causes  
 (a) Addison's disease (b) Cushing's disease  
 (c) Dwarfism (d) Simmond's disease
30. A chemical signal that has both endocrine and neural roles is  
 [AIPMT (Cancelled) 2015]  
 (a) Calcitonin (b) Epinephrine  
 (c) Cortisol (d) Melatonin
31. A substance called ADH is [CBSE PMT 1991]  
 (a) A hormone that promotes glycogenesis in liver cells  
 (b) An enzyme secreted by cell of intestinal wall; hydrolyses dipeptides into amino acids  
 (c) A pituitary secretion which promotes reabsorption of water from glomerular filtrate  
 (d) A high energy compound involved in muscle contraction
32. The co-ordinator between Nervous and endocrine system is  
 [MHCET 2015]

Or

- Oxytocin is synthesized in [WB JEE 2016]  
 (a) Thalamus (b) Hypothalamus  
 (c) Epithalamus (d) Colliculus
33. Growth hormone activity [CPMT 1993]  
 (a) Decreases with thyroxine (b) Increases with thyroxine  
 (c) Remains same (d) None of these
34. Pituitary gland is found in [MP PMT 1994, 98]  
 (a) Brain (b) Trachea  
 (c) Gonads (d) Pancreas
35. A person entering an empty room suddenly finds a snake right in front on opening the door. Which one of the following is likely to happen in his neuro-hormonal control system [CBSE PMT (Pre.) 2012]  
 (a) Sympathetic nervous system is activated releasing epinephrin and norepinephrin from adrenal medulla  
 (b) Neurotransmitters diffuse rapidly across the cleft and transmit a nerve impulse  
 (c) Hypothalamus activates the parasympathetic division of brain  
 (d) Sympathetic nervous system is activated releasing epinephrin and norepinephrin from adrenal cortex
36. FSH is a [RPMT 2000]  
 (a) Catecholamine (b) Glycoprotein  
 (c) Polypeptide (d) Steroid

37. Match List I with List II and select the correct option

List I		List II	
A.	Adrenalin	1.	Myxoedema
B.	Hyperparathyroidism	2.	Accelerates heart beat
C.	Oxytocin	3.	Salt-water balance
D.	Hypothyroidism	4.	Childbirth
E.	Aldosterone	5.	Demineralisation

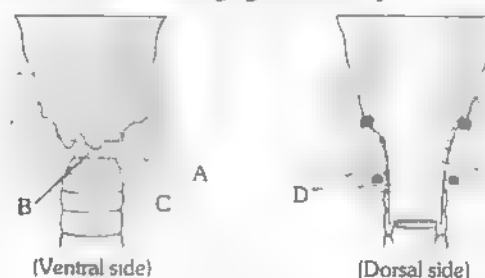
[DPMT 2006; Kerala PMT 2008; CPMT 2010]

- (a) A - 2, B - 5, C - 4, D - 1, E - 3  
 (b) A - 3, B - 4, C - 5, D - 3, E - 2  
 (c) A - 5, B - 3, C - 2, D - 4, E - 1  
 (d) A - 2, B - 3, C - 4, D - 5, E - 1  
 (e) A - 5, B - 3, C - 4, D - 2, E - 1
38. Gonadotrophic hormones are produced in the [MP PMT 1995; CBSE PMT 1999; CPMT 2010]  
 (a) Posterior part of thyroid  
 (b) Adrenal cortex  
 (c) Adenohypophysis of pituitary  
 (d) Interstitial cells of testis
39. Injury localized to the hypothalamus would most likely disrupt [CBSE PMT 2014]  
 (a) Executive function, such as decision making  
 (b) Regulation of body temperature  
 (c) Short term memory  
 (d) Co-ordination during locomotion
40. Adrenaline is equivalent to which neurotransmitter [Odisha JEE 2009]  
 (a) GABA (b) Serotonin  
 (c) Epinephrine (d) Norepinephrine
41. Steroid hormones easily pass through the plasma membrane by simple diffusion because they [DUMET 2009]  
 (a) Are water soluble  
 (b) Contain carbon and hydrogen  
 (c) Enter through pores  
 (d) Are lipid soluble
42. If the pituitary gland of an adult rat is surgically removed, which of the following endocrine gland will be less affected [DUMET 2009]  
 (a) Adrenal cortex (b) Adrenal medulla  
 (c) Thyroid (d) Gonads
43. Select the correct option describing gonadotropin activity in a normal pregnant female [CBSE PMT 2014]  
 (a) High level of hCG stimulates the synthesis of estrogen and progesterone  
 (b) High level of hCG stimulates the thickening of endometrium  
 (c) High level of FSH and LH stimulates the thickening of endometrium  
 (d) High level of FSH and LH facilitate implantation of the embryo

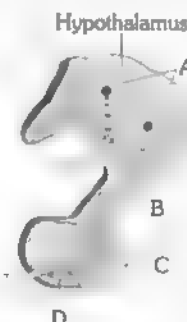
44. Estrogen and testosterone are steroid hormones, and are most likely bind to [Odisha JEE 2009; DUMET 2009; KCET 2011]
- Membrane ions channels
  - Enzyme-linked membrane receptors
  - G-protein linked membrane receptors
  - Cytoplasmic receptors
45. Which of the following secretes leutenizing hormone [CPMT 1995]
- Pituitary
  - Thyroid
  - Parathyroid
  - Adrenal
46. Pitressin is also called as [CPMT 1995]
- ADH
  - LH
  - NADH
  - FSH
47. Which of the following hormones regulates growth and metamorphosis in insects [DUMET 2009]
- Juvenile hormone
  - Brain hormone
  - Ecdyson
  - Prothoracicotropic hormone
48. Depict the correct site of hormone [NCERT; RPMT 1995; DPMT 2007]
- $\alpha$ -glucagon,  $\beta$ -insulin,  $\delta$ -somatostatin
  - $\alpha$ -insulin,  $\beta$ -glucagon,  $\delta$ -somatostatin
  - $\delta$ -insulin,  $\alpha$ -somatostatin,  $\beta$ -glucagon
  - $\alpha$ -somatostatin,  $\beta$ -insulin,  $\delta$ -glucagon
49. Glycosuria is the condition, where a man [DUMET 2009; WB JEE 2010]
- Eats more sugar
  - Excretes sugar in urine
  - Sugar is excreted in faeces
  - Has low sugar level in blood
50. Cortisol is secreted by the adrenal cortex in response to stress. In addition to its function in a stress response, it functions in negative feedback by [J & K CET 2012]
- Inhibiting the hypothalamus so that corticotropin releasing hormone (CRH) secretion is reduced
  - Inhibiting the anterior pituitary's ability to respond to CRH by reducing the pituitary's sensitivity to CRH
  - Both (a) and (b) are correct
  - None of these
51. RAAS secretes which of the following hormone [NCERT; DPMT 2007]
- Mineralocorticoids
  - Glucocorticoids
  - Both (a) and (b)
  - None of these
52. Which one controls the secretion of oestrogen [MP PMT 1997]
- hCG
  - Progesteron
  - LH
  - FSH
53. Which one of the following is not a second messenger in hormone action [CBSE PMT 2006; WB JEE 2011]
- Sodium
  - cAMP
  - cGMP
  - Calcium
54. Fight-or-flight reactions cause activation of [NCERT; CBSE PMT 2014]
- The adrenal medulla, leading to increased secretion of epinephrine and norepinephrine
  - The pancreas leading to a reduction in the blood sugar levels
  - The parathyroid glands, leading to increased metabolic rate
  - The kidney, leading to suppression of reninangiotensin-aldosterone pathway
55. At cellular level GH affects growth by controlling the production of [MP PMT 2000, 06]
- r-RNA
  - t-RNA
  - m-RNA
  - None of the above
56. The synthesis of vasopressin is done by [RPMT 2001]
- Hypothalamus
  - Kidney
  - Anterior pituitary
  - Posterior pituitary
57. A person passes much urine and drinks much water but his blood glucose level is normal. This condition may be the result of [AIIMS 2003]
- A reduction in insulin secretion from pancreas
  - A reduction in vasopressin secretion from posterior pituitary
  - A fall in the glucose concentration in urine
  - An increase in secretion of glucagon
58. A man is admitted to a hospital. He is suffering from an abnormally low body temperature, loss of appetite and extreme thirst. His brain scan would probably show a tumor in [KCET 2009]
- Medulla oblongata
  - Pons
  - Cerebellum
  - Hypothalamus
59. See the following figures and identify it [NCERT]
- 
- Kidney
- A - Adrenal gland, B - Fat, C - Pars distalis, D - Pars intermedia
  - A - Adrenal gland, B - Fat, C - Medulla, D - Cortex
  - A - JGA, B - Fat, C - Cortex, D - Medulla
  - A - Adrenal gland, B - Fat, C - Cortex, D - Medulla
60. Thyrotropin-Releasing Factor (TRF) is produced by [MP PMT 2002]
- Cerebrum
  - Optic lobe
  - Cerebellum
  - Hypothalamus
61. Similarity between the secretion of thyroid and adrenal is that both the secretions [AIIMS 1992]
- Are proteins
  - Are steroid
  - Increase glucose metabolism
  - Control mineral metabolism

62. Calcitonin lowers the calcium level in the blood. This is secreted by [CBSE PMT 1992; CPMT 1998; MP PMT 2013]  
 (a) Parathyroid (b) Hypothalamus  
 (c) Adrenal (d) Thyroid
63. Select the incorrect statement [NEET (Phase-I) 2016]  
 (a) FSH stimulates the sertoli cells which help in spermiogenesis  
 (b) LH triggers ovulation in ovary  
 (c) LH and FSH decrease gradually during the follicular phase  
 (d) LH triggers secretion of androgens from the leydig cells
64. Disease caused by deficiency of iodine is [CBSE PMT 1993; MP PMT 1999; HP PMT 2005; MH CET 2007]  
 (a) Goitre (b) Myxodema  
 (c) Cretinism (d) Tetany
65. Which disease is caused by the deficiency of thyroxine in the adults [Pb. PMT 2000; MP PMT 2000]  
 (a) Diabetes incipidus (b) Diabetes mellitus  
 (c) Myxoedema (d) Exophthalmic goitre
66. Acromegaly results after adolescence due to excess production of one of the following hormones [MP PMT 2001; AIIMS 2001; CBSE PMT 2002; Kerala CET 2002]  
 (a) Prolactin (b) Thyroxin  
 (c) Insulin (d) STH
67. An organ X has a large blood supply. It produces a hormone lack of which causes a disease called as cretinism. The cause is [NCERT]  
 Or  
 Cretinism is due to [CPMT 1992, 93, 2004; MP PMT 1993, 99; 2013; CMC Vellore 1993; WB JEE 2011]  
 (a) Excess growth hormone  
 (b) Absence of insulin  
 (c) Excess adrenalin  
 (d) Hyposecretion of thyroid in childhood (Thyroxin)
68. 'Exophthalmic goitre' (Grave's disease) is caused due to [NEET (Phase-II) 2016]  
 (a) Hypofunction of the thyroid  
 (b) Hyperfunction of the thyroid  
 (c) Hypofunction of the parathyroid  
 (d) Hyperfunction of the parathyroid
69. Which of the following hormones does not contain a polypeptide [KCET 2009]  
 (a) Prostaglandin (b) Oxytocin  
 (c) Insulin (d) Antidiuretic hormone
70. Damage to thymus in a child may lead to [AIIMS 2007; KCET 2009]  
 (a) Loss of cell mediated immunity  
 (b) A reduction in the haemoglobin content in blood  
 (c) A reduction in the amount of plasma proteins  
 (d) Loss of antibody mediated immunity
71. Which hormone causes dilation of blood vessels, increased oxygen consumption and glucogenesis [CBSE PMT 2006]  
 (a) Adrenalin (b) Glucagon  
 (c) ACTH (d) Insulin

72. Consider the following figures Identify A to D [NCERT]



- (a) A - Thyroid, B - Corpus luteum, C - Trachea, D - Parathyroid gland  
 (b) A - Thyroid, B - Isthmus, C - Larynx, D - Parathyroid gland  
 (c) A - Thyroid, B - Isthmus, C - Trachea, D - Parathyroid gland  
 (d) A - Parathyroid gland, B - Isthmus, C - Trachea, D - Thyroid
73. Which of the following hormone is not involved in tyrosine metabolism [CPMT 2010]  
 (a) Calcitonin (b) Melanin  
 (c) Thyroxine (d) Epinephrine
74. See the given diagrammatic representation. Identify A, B, C and D [NCERT]



- (a) A - Hypothalamic neurons, B - Portal circulation, C - Posterior pituitary, D - Anterior pituitary  
 (b) A - Hypothalamic neurons, B - Portal circulation, C - Anterior pituitary, D - Posterior pituitary  
 (c) A - Epithalamic neurons, B - Hypothalamic vein, C - Pars distalis, D - Pars intermedia  
 (d) A - Hypothalamic neurons, B - Hypothalamic artery, C - Posterior pituitary, D - Anterior pituitary
75. An adenohypophysis hormone which is regulated by feedback mechanism is [Kerala PMT 2009]  
 (a) Oxytocin (b) TSH  
 (c) Vasopressin (d) Cortisone  
 (e) Calcitonin
76. Match the hormones with its source of secretion
- |     |              |     |                     |
|-----|--------------|-----|---------------------|
| (A) | Somatostatin | (1) | Pineal gland        |
| (B) | Melatonin    | (2) | Corpus luteum       |
| (C) | Aldosterone  | (3) | Placenta            |
| (D) | Progesterone | (4) | Adrenal cortex      |
| (E) | HCG          | (5) | Islet of Langerhans |
|     |              | (6) | Adenohypophysis     |
- [Kerala PMT 2009; CPMT 2010]  
 (a) (A) — (5), (B) — (1), (C) — (6), (D) — (3), (E) — (2)  
 (b) (A) — (1), (B) — (2), (C) — (4), (D) — (3), (E) — (5)  
 (c) (A) — (2), (B) — (6), (C) — (4), (D) — (5), (E) — (3)  
 (d) (A) — (5), (B) — (1), (C) — (4), (D) — (2), (E) — (3)  
 (e) (A) — (1), (B) — (3), (C) — (4), (D) — (2), (E) — (5)

77. The source of somatostatin is same as that of [AIIMS 2003]  
 (a) Thyroxine and calcitonin  
 (b) Insulin and glucagon  
 (c) Somatotropin and prolactin  
 (d) Vasopresin and oxytocin

78. The chemical substances released by activated spermatozoa that acts on the ground substances of the follicle cells is known as [Kerala PMT 2009]

- (a) Progesterone (b) Hyaluronidase  
 (c) Relaxin (d) Gonadotropin  
 (e) Teratogen

79. Match list I with list II and choose the correct answer

List I		List II	
(A)	Hypothalamus	(1)	Sperm lysins
(B)	Acrosome	(2)	Estrogen
(C)	Graafian follicle	(3)	Relaxin
(D)	Leydig cells	(4)	GnRH
(E)	Parturition	(5)	Testosterone

[Kerala PMT 2009]

- (a) (A) — (4), (B) — (1), (C) — (2), (D) — (3), (E) — (5)  
 (b) (A) — (2), (B) — (1), (C) — (4), (D) — (3), (E) — (5)  
 (c) (A) — (2), (B) — (1), (C) — (5), (D) — (4), (E) — (3)  
 (d) (A) — (4), (B) — (1), (C) — (2), (D) — (5), (E) — (3)  
 (e) (A) — (5), (B) — (1), (C) — (3), (D) — (2), (E) — (4)

80. Which one of the following hormone never reaches to cytoplasm [BHU 2008]

- (a) Estrogen (b) FSH  
 (c) Progesterone (d) Testosterone

81. Find the odd one out [BHU 2008]

- (a) Parathyroid — tetany  
 (b) Pancreas — diabetes insipidus  
 (c) Adrenal cortex — Cushing's syndrome  
 (d) Thyroid — goitre

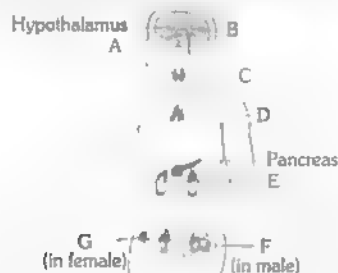
82. Which endocrine gland stores its secretion in the extracellular space before discharging it into the blood [CBSE PMT 1995; Odisha JEE 2005]

- (a) Adrenal (b) Pancreas  
 (c) Testis (d) Thyroid

83. Which of the following radioactive isotopes is used in the detection of thyroid cancer [CBSE PMT 1995]

- (a) Iodine-131 (b) Carbon-14  
 (c) Uranium-238 (d) Phosphorus-32

84. See the given figure which related with principal endocrine glands in human. Identify A to G [NCERT]



- (a) A - Pituitary, B - Pineal, C - Thyroid and parathyroid, D - Thymus, E - Adrenal, F - Testis, G - Ovary  
 (b) A - Pituitary, B - Pineal, C - Thyroid and parathyroid, D - Thymus, E - Kidney, F - Testis, G - Ovary  
 (c) A - Pituitary, B - Pineal, C - Thyroid and parathyroid, D - Thymus, E - Adrenal, F - Ovary, G - Testis  
 (d) A - Pineal, B - Pituitary, C - Thyroid and parathyroid, D - Thymus, E - Adrenal, F - Testis, G - Ovary

85. Adrenal gland is derived from [MP PMT 2007]

- (a) Ectoderm (b) Mesoderm  
 (c) Ectoderm and mesoderm (d) Ectoderm and endoderm

86. Which of the following is not an endocrine gland [Odisha JEE 2010]

Or

Which of the following does not secrete any hormones

- (a) Liver/spleen (b) Pancreas  
 (c) Testes (d) Thymus

87. Melanin is secreted by [MP PMT 2013]

- (a) Erythroblasts of blood  
 (b) Chromatophores of skin  
 (c) Cells of stratum compactum  
 (d) Ganglia of sensory nerves

88. Which of the following hormones has no effect on heart beat [AFMC 2012]

- (a) Thyroxine (b) Oxytocin  
 (c) Adrenaline (d) Noradrenaline

89. Which of the following glands is associated with the consumption of iodized salt [RPMT 1995; CPMT 1999; JIPMER 2001]

Or

Thyroxine is secreted by [RPMT 1999]

- (a) Thyroid (b) Thymus  
 (c) Pituitary (d) Ovary

90. The hormone which regulates the basal metabolism in our body, is secreted from [CPMT 1998]

- (a) Pituitary (b) Thyroid  
 (c) Adrenal cortex (d) Pancreas

91. Hormones thyroxine, adrenaline and the pigment melanin are formed from [CBSE PMT 1997]

- (a) Tryptophan (b) Glycine  
 (c) Tyrosine (d) Proline

92. Iodine is associated with [CBSE PMT 1997; BHU 2001; WB JEE 2016]

- (a) Thyroxine (b) Calcitonin  
 (c) Oxytocin (d) Secretin

93. \_\_\_\_\_ is a globular protein of ~6 kDa consisting of 51 amino acids, arranged in 2 polypeptide chains held together by disulphide bridge [AMU (Med.) 2012]

- (a) Insulin (b) Keratin  
 (c) Glucagon (d) Fibrinogen

94. Which of the following gland plays a key role in metamorphosis of frog's tadpole [AIIMS 1999; CPMT 2003]

- (a) Adrenal (b) Thymus  
 (c) Pancreas (d) Thyroid

95. Goitre affects [MP PMT 2000]

- (a) Metabolism (b) Vision  
 (c) Excretion (d) Speech

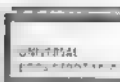
96. Why thyroxine is a hormone not an enzyme [RPMT 2001]

- (a) It is secreted in small quantity  
 (b) It is not a polypeptide  
 (c) It has no special effect  
 (d) It is directly poured into blood

97. The other name for autoimmune thyroiditis is  
[RPMT 1995; MP PMT 2001; BHU 2002; JIPMER 2002]  
Or  
An autoimmune disease where the body's own antibodies attack the cells of thyroid is [MP PMT 2007]  
(a) Addison's disease (b) Simmond's disease  
(c) Hashimoto's disease (d) Cushing's disease
98. Toxic agents present in food which interfere with thyroxine synthesis lead to the development of [CBSE PMT (Pre.) 2010]  
Or  
Disease related to thyroxine hormone [CPMT 2003]  
(a) Thyrotoxicosis (b) Toxic goitre  
(c) Cretinism (d) Simple goitre
99. 'Royal jelly' is secreted from [WB JEE 2008]  
(a) Hypopharyngeal gland (b) Salivary gland  
(c) Milk gland (d) Integumentary gland
100. Hypoparathyroidism results to  
(a) Upset in metabolism  
(b) Improper gonodial function  
(c) Convulsions and tetany  
(d) Nervousness and wasting
101. Parathormone induces [CPMT 1991, 92, 93; MP PMT 1996, 97, 2002; Pb. PMT 1999; RPMT 2000; BHU 2000; AMU (Med.) 2006]  
(a) Increase in serum calcium level  
(b) Decrease in serum potassium level  
(c) Increase in blood sugar level  
(d) Decrease in blood sugar level
102. If parathyroid gland of a child is removed, which activity is disturbed [CPMT 1993; AIIMS 2013]  
(a) Growth (b) Calcium concentration  
(c) Potassium concentration (d) None of these
103. Diabetes mellitus is caused due to [Odisha JEE 2012]  
(a) Underproduction of insulin  
(b) Underproduction of glycogen  
(c) Overproduction of insulin  
(d) Overproduction of glycogen
104. In case the islets of Langerhans stop functioning which hormone will be in short supply and what will be its effect [MP PMT 2006]  
(a) Insulin—Blood glucose level will rise  
(b) Adrenaline—Heart beat will increase  
(c) Thyroxin—Growth will be retarded  
(d) Cortine—Tetany will develop
105. Hypokalaemia means [MP PMT 2011]  
(a) High level of potassium in blood  
(b) High level of sodium in blood  
(c) Low level of potassium in blood  
(d) Low level of sodium in blood
106. Most of the contraceptive pills contain [CBSE PMT 1998, 99; BVP 2002; AFMC 2009; WB JEE 2012]  
(a) Estrogen + FSH (b) Progesterone + LH  
(c) FSH + LH (d) Oestrogen + progesterone
107. Insulin increases glucose uptake in all the following structures except [CBSE PMT 2001]  
(a) Cardiac muscle (b) Skeletal muscle  
(c) Adipose tissue (d) Intestinal mucosa
108. Parathormone is secreted during [J & K CET 2002; RPMT 2005]  
(a) Increased blood calcium level  
(b) Decreased blood calcium level  
(c) Increased blood sugar level  
(d) Decreased blood sugar level
109. Which of the following pairs of hormones are not antagonistic (having opposite effects) to each other [NEET (Phase-I) 2016]  
(a) Parathormone - Calcitonin  
(b) Insulin - Glucagon  
(c) Aldosterone - Atrial Natriuretic Factor  
(d) Relaxin - Inhibin
110. Angiotensin is derived from plasma protein "angiotensinogen" by the action of renin and other nervous stimuli. Angiotensin stimulates the following [CBSE PMT 1992]  
(a) Thyroid (b) Adrenal  
(c) Ovary (d) Thymus
111. The hormones that initiate ejection of milk, stimulates milk production and growth of ovarian follicles are respectively known as [Kerala PMT 2006]  
(a) PRL, OT and LH (b) OT, PRL and FSH  
(c) LH, PRL and FSH (d) PRH, OT and LH  
(e) PRH, OT and FSH
112. The mineralocorticoid hormone of the adrenal cortex which causes the Na retention and K excretion is [NCERT; CMC Vellore 1993; Kerala PMT 2010; WB JEE 2011]  
Or  
Conn's disease is caused by the over-secretion of [AIIMS 1999]  
(a) Corticisol (b) Corticosterone  
(c) Progesterone (d) Aldosterone
113. Which one of the following cells, found in testes of rabbit secretes male hormone [CBSE PMT 1998]  
(a) Leydig's cell (b) Sertoli cells  
(c) Epithelial cells (d) Spermatocytes
114. Which one of the following hormone controls the water and mineral metabolism  
(a) Progesterone (b) Insulin  
(c) Succus entericus (d) Deoxycorticosterone
115. If a human female starts developing male characteristics like bearded, degeneration of uterus and ovaries, enlargement of clitoris etc. It may be due to  
(a) Over production oestrogen and testosterone  
(b) Damage to posterior pituitary  
(c) Over production of adrenal androgens  
(d) Surgical removal of mammary gland
116. Which is not a gonadal hormone [MP PMT 1993]  
(a) Progesterone (b) Testosterone  
(c) Adrenalin (d) Oestrogen
117. Goitre can occur as a consequence of all the following except [WB JEE 2009]  
(a) Iodine deficiency  
(b) Pituitary adenoma  
(c) Grave's disease  
(d) Excessive intake of exogenous thyroxine

118. Cushing's syndrome and myxoedema are associated with these glands respectively [CBSE PMT 1993]  
(a) Thyroid, adrenal (b) Adrenal, thyroid  
(c) Parathyroid, thyroid (d) Adrenal, pituitary
119. Cholecystokinin and secretin are [CBSE PMT 1990; JIPMER 1993; MP PMT 1994, 95]  
(a) Hormones liberated by mucosa of duodenum and stimulate gall bladder and pancreas respectively  
(b) Hormones stimulating liver  
(c) Hormones stimulating pancreas  
(d) Enzymes
120. Deficiency in the activity of adrenal cortex leads to [MP PMT 2002, 06]  
(a) Addison's disease (b) Simmond's disease  
(c) Cohn's syndrome (d) Cushing's disease
121. Which of the following hormone governs the metabolism of carbohydrates [CBSE PMT 1993]  
(a) Corticoids (b) Glucagon  
(c) Insulin (d) Glucagon and insulin
122. Which one of the following is both hormone and enzyme [RPMT 2000]  
(a) ADH hormone (b) Acetylcholinesterase  
(c) Angiotensinogen (d) Renin
123. Blood pressure is controlled by [NCERT; MP PMT 2004]  
(a) Adrenal (b) Thyroid  
(c) Thymus (d) Corpus luteum
124. Which of the following endocrine glands functions under nervous control  
(a) Cortex of adrenal glands (b) Medulla of adrenal glands  
(c) Anterior pituitary glands (d) Posterior pituitary gland
125. Insulin is secreted by [BVP 2001; Odisha PMT 2002; CPMT 2003]  
(a) Pituitary (b) Pancreas  
(c) Gonads (d) Thymus
126. Adrenal cortex secretes androgen, it is [CPMT 1992, 93]  
(a) Testosterone (b) Androsterone  
(c) Progesterone (d) Aldosterone
127. Adrenal glands are found located in abdominal cavity in close association with [MP PMT 1994; AFMC 2003; Odisha JEE 2012]  
Or  
Which one of the following is not a gland [AFMC 2003]  
(a) Testes (b) Spleen  
(c) Liver (d) Kidneys
128. The genetic deficiency of ADH-receptor leads to [MP PMT 2001; WB JEE 2008, 09]  
(a) Diabetes mellitus (b) Glycosuria  
(c) Diabetes insipidus (d) Nephrogenic diabetes
129. Which of the following is correctly matched [AFMC 2009, 10]  
(a) Thyroxine - tetanus (b) Insulin - diabetes insipidus  
(c) Adrenaline - hepatitis (d) Parathyroid - tetany
130. Catecholamine in a normal person induces [AIIMS 2012]  
(a) Intense salivation (b) Alertness  
(c) Decrease in heart beat (d) Excessive urination
131. Hormone involved in the discharge of pancreatic juice in mammals is  
(a) Secretin (b) Gastrin  
(c) Cholecystokinin (d) Enterogasterone
132. Hypothyroidism in adults and hyperparathyroidism will respectively lead to [Kerala PMT 2006]  
(a) Myxoderma and Cretinism  
(b) Grave's disease and Hashimoto's disease  
(c) Myxoedema and Osteitis fibrosa cystica  
(d) Addison's disease and Cretinism  
(e) Cretinism and Osteitis fibrosa cystica
133. Which one of the following pairs is incorrectly matched [CBSE PMT (Pra.) 2010]  
(a) Insulin-Diabetes mellitus (Disease)  
(b) Glucagon-Beta cells (Source)  
(c) Somatostatin-Delta cells (Source)  
(d) Corpus luteum-Relaxin (Secretion)
134. The main function of nor-adrenaline is [CPMT 1995]  
(a) Contraction of arteries  
(b) To stop contraction of arteries  
(c) Relaxation  
(d) None of the above
135. Cause of Addison's disease is [CPMT 1996, 99; AIIMS 1998; MP PMT 2003]  
(a) Hyposecretion of aldosterone hormone  
(b) Hypersecretion of aldosterone hormone  
(c) Hyposecretion of cortisone hormone  
(d) Hypersecretion of cortisone hormone
136. Life saving hormone is secreted by which gland [MP PMT 1999]  
(a) Adrenal gland (b) Hypothalamus gland  
(c) Pituitary gland (d) Thyroid gland
137. Which hormone can increase rate of formation of glycogen, volume of blood in vessel and rate of heart beat [KCET 1994; CPMT 1998]  
(a) Insulin (b) Glucagon  
(c) Adrenalin (d) FSH
138. Which of the following hormones is a derivative of amino acid [AIIMS 1999; MP PMT 2010; Kerala PMT 2010, 11]  
(a) Oestrogen (b) Epinephrine  
(c) Progesterone (d) Prostaglandin
139. Glucagon hormone is secreted by [CBSE PMT 1993]  
(a) Pituitary  
(b) Adrenal  
(c) Beta cells of islets of Langerhans  
(d) Alpha cells of islets of Langerhans
140. Nor epinephrine is secreted from [RPMT 2000]  
(a) Zona glomerulosa (b) Zona fasciculata  
(c) Zona reticularis (d) Medulla of adrenal
141. Which gland is concerned with salt equilibrium in body [RPMT 2001]  
(a) Anterior pituitary (b) Pancreas  
(c) Adrenal (d) Thyroid





142. Which one affects liver, muscle and adipose tissue

[BHU 2003]

Or

Name a peptide hormone which acts mainly on hepatocytes, adipocytes and enhances cellular glucose uptake and utilization [NEET (Phase-II) 2016]

- (a) Androgen (b) Insulin  
(c) Progesterone (d) Glucagon

143. Hassal's bodies/corpuscles

[DPMT 2006]

- (a) Adrenal medulla (b) Thyroid  
(c) Thymus (d) Parathyroid

144. Norepinephrine

[RPMT 2006; NEET (Karnataka) 2013]

- (A) Is released by sympathetic fibers  
(B) Is released by parasympathetic fibers  
(C) Increases the heart rate  
(D) Decreases blood pressure

Which of the above said statements are correct

- (a) (A) and (C) (b) (B) and (C)  
(c) (B) and (D) (d) (A) and (D)

145. Pineal body originates from

[MP PMT 2003]

- (a) Dorsal part of diencephalon  
(b) Ventral part of diencephalon  
(c) Ventral part of cerebellum  
(d) Dorsal part of cerebellum

146. According to recent knowledge, the pineal body is considered as

- (a) A vestigial organ  
(b) An organ of intelligence  
(c) An endocrine gland  
(d) An organ of involuntary action

147. Identify the hormone with its correct matching of source and function [CBSE PMT 2014]

- (a) Progesterone – corpus-luteum, stimulation of growth and activities of female secondary sex organs  
(b) Atrial natriuretic factor – ventricular wall increases the blood pressure  
(c) Oxytocin – posterior pituitary, growth and maintenance of mammary glands  
(d) Melatonin – pineal gland, regulates the normal rhythm of sleepwake cycle

148. Daily rhythms are usually associated with

[CPMT 1999; JIPMER 2001]

Or

One of the following endocrine gland functions as a biological clock and a neurosecretory transducer

[Kerala PMT 2006]

- (a) Pineal (b) Pituitary  
(c) Thymus (d) Hypothalamus

149. In a pregnant woman having prolonged labour pains, if child birth has to be hastened i.e. to aid parturition, it is advisable to administer a hormone that can [DPMT 1993]

- (a) Activate the smooth muscles  
(b) Increase the metabolic rate  
(c) Release glucose into the blood  
(d) Stimulate the ovary

150. Which one of the following statement about sex hormones is correct [MP PMT 1992]

- (a) Testosterone is produced by Leydig cells under the influence of luteinizing hormone (LH)  
(b) Progesterone is secreted by corpus luteum and softens ligaments during child birth  
(c) Estrogen is secreted by both Sertoli cells and corpus luteum  
(d) The progesterone produced by corpus luteum is biologically different from the one produced by placenta

151. Luteinizing hormone

[KCET 1994]

- (a) Stimulates ovulation  
(b) Stimulates the egg mother cell to undergo completion of meiotic cycle  
(c) Stimulates the corpus luteum to secrete progesterone  
(d) All of the above

152. Testosterone, a hormone responsible for the development of secondary sexual characteristics in male is produced by the

[AIIMS 1992]

- (a) Spermatogonia  
(b) Seminiferous tubules  
(c) Anterior lobe of the pituitary  
(d) Cells that lie between seminiferous tubules

153. Parathormone influences calcium absorption in the small intestine by regulating the metabolism of

[AMU (Med.) 2010; DUMET 2010]

- (a) Vitamin C (b) Vitamin D  
(c) Vitamin B<sub>6</sub> (d) Enterogasterone

154. Continued secretion of milk is maintained by

[MP PMT 1993; CPMT 2001, 03; MH CET 2006]

Or

Which of the following is a lactogenic hormone

[MP PMT 2013]

- (a) Prolactin (b) Progesterone  
(c) Estrogen (d) Relaxin

155. Signal from fully developed foetus and placenta ultimately lead to parturition (child birth) which requires the release of

[NCERT; DPMT 1993; CBSE PMT 1999; CPMT 2001; CBSE PMT (Mains) 2010; NEET (Karnataka) 2013]

- (a) Estrogen from placenta  
(b) Oxytocin from maternal pituitary  
(c) Oxytocin from foetal pituitary  
(d) Relaxin from placenta

156. Progesterone hormone is secreted by [NCERT; CPMT 2001; MP PMT 1994, 96, 2009; BHU 2003; CBSE PMT 2014]

- (a) Corpus luteum (b) Corpus callosum  
(c) Corpus uteri (d) Corpus albicans

157. Diabetes is due to

[CBSE PMT 1999]

- (a) Na<sup>+</sup> deficiency (b) Hormonal deficiency  
(c) Enzyme deficiency (d) Iodine deficiency

158. Hormone responsible for the implantation of embryo in uterus and formation of placenta is [BHU 1999]

Or

Pregnancy hormone is

[CPMT 1994]

- (a) Adrenalin (b) Progesterone  
(c) Estradiol (d) FSH

159. Graafian follicles are formed by the active division of

- (a) Peritoneum
- (b) Generative epithelium
- (c) Columnar epithelium (sensory)
- (d) Corpus cavernosa

160. Insulin receptors are

- (a) Extrinsic protein
- (b) Intrinsic protein
- (c) G-protein
- (d) Trimeric protein

161. The 24 hour (diurnal) rhythm of our body such as the sleep-wake cycle is regulated by the hormone

[NCERT; Kerala PMT 2010; MP PMT 2011; CBSE PMT (Mains) 2011]

Or

Which hormone is secreted more in dark condition

[MP PMT 2000]

- (a) Adrenaline
- (b) Melatonin
- (c) Calcitonin
- (d) Prolactin

162. Which one of the following is temporary endocrine gland

[NEET 2017]

- (a) Pineal
- (b) Pancreas
- (c) Placenta (corpus luteum)
- (d) Parathyroid

163. Female sex hormone is

[MP PMT 1993]

Or

Which of the following hormone is not chemically glycoprotein

[WB JEE 2016]

- (a) Androgen
- (b) Adrenalin
- (c) Insulin
- (d) Estrogen

164. Which hormone is secreted at the time of parturition

[MP PMT 1993]

- (a) Progesterone
- (b) Thyroxin
- (c) Relaxin
- (d) Glucocorticoid

165. Match the items in Column – I with Column – II and choose the correct alternative

Column – I

Column – II

- |                   |   |                               |
|-------------------|---|-------------------------------|
| A. Calcitonin     | 1 | Treatment of viral infections |
| B. Gonadotropin   | 2 | Treatment of rickets          |
| C. Erythropoietin | 3 | Enhancement of immune action  |
| D. Interferon     | 4 | Formation of erythrocytes     |
| E. Interleukin    | 5 | treatment of infertility      |

[Kerala PMT 2007]

- (a) A-3, B-1, C-4, D-2, E-5
- (b) A-3, B-2, C-1, D-5, E-4
- (c) A-4, B-3, C-2, D-1, E-5
- (d) A-2, B-3, C-4, D-5, E-1
- (e) A-2, B-5, C-4, D-1, E-3

166. The effect of prolactin will be marked in

[MP PMT 1993]

- (a) Bones
- (b) Pancreas
- (c) Mammary gland
- (d) Liver

167. 'Islets of Langerhans' are found in

[MP PMT 1994, 98; JIPMER 2002; BHU 2006; WB JEE 2010]

- (a) Pancreas
- (b) Pituitary
- (c) Stomach
- (d) Spleen

168. Cholesterol is necessary for the synthesis of

- (a) Vitamin C
- (b) Vitamin B
- (c) Oestradiol
- (d) Insulin

169. Which one of the following statements is incorrect

[WB JEE 2012]

- (a) Glucagon is secreted by pancreas
- (b) Androgen is produced by ovary
- (c) Thyroxine is secreted by thyroid
- (d) Oxytocin is secreted by pituitary

170. Which of the following is known as master endocrine gland

[Odisha JEE 2012]

- (a) Adrenal gland
- (b) Thyroid gland
- (c) Pituitary gland
- (d) Pineal gland

171. The rise of blood sugar above the normal level is known as

[DPMT 1993]

- (a) Hyperglycemia
- (b) Hypoglycemia
- (c) Glucosuria
- (d) Glycolysis

172. A disease characterised by raised levels of blood glucose as well as increased fat and protein metabolism is

[CBSE PMT 1993]

- (a) Diabetes
- (b) Cancer
- (c) Ulcer
- (d) Enlargement of pancreas

173. Steroid hormones regulate gene activity through

[AFMC 1993]

- (a) Transcription
- (b) Binding with specific DNA sites
- (c) Removing the repressor molecules
- (d) The formation of a receptor complex

174. A polypeptide secreted into the blood by the cells in the stomach wall, stimulates the production of HCl by the parietal cells of the stomach is

[CBSE PMT 1993]

- (a) Gastrin
- (b) Secretin
- (c) Pancreozymin
- (d) Renin

175. Function of relaxin hormone is

- (a) Relax pubic symphysis
- (b) Relax ovaries
- (c) Relax uterus
- (d) Relax fallopian tubule

176. Insulin was isolated from dog by

- (a) M Bayliss
- (b) E H. Sterling
- (c) Banting and Best
- (d) Von Mering

177. Given below is an incomplete table about certain hormones, their source glands and one major effect of each on the body in humans. Identify the correct option for the three blanks A, B and C

Glands	Secretion	Effect on body
A	Oestrogen	Maintenance of secondary sexual character
Alpha cells of Islets of Langerhans	B	Raises blood sugar level
Anterior pituitary	C	Over secretion leads to gigantism

Options [NCERT; CBSE PMT (Pre.) 2011]

- | A            | B        | C              |
|--------------|----------|----------------|
| (a) Placenta | Glucagon | Calcitonin     |
| (b) Ovary    | Glucagon | Growth hormone |
| (c) Placenta | Insulin  | Vasopressin    |
| (d) Ovary    | Insulin  | Calcitonin     |

178. Which hormone stimulates the secretion of milk during sucking of milk by baby [CBSE PMT 1996]

Or

Which hormone is responsible for milk ejection after the birth of the baby [MP PMT 2007; WB JEE 2010]

- (a) Oxytocin (b) Relaxin  
(c) Prolactin (d) Progesteron
179. Which hormone among these is not secreted by an endocrine gland [Kerala PMT 2012]
- (a) ADH (b) ANF  
(c)  $T_4$  (d) PTH  
(e) MSH

180. Choose the mismatched pair from the following [KCET 2012]

- (a) Insulin – Gluconeogenesis  
(b) Glucagon – Glycogenolysis  
(c) Oxytocin – Contraction of uterine muscles  
(d) Prolactin – Milk production in mammary glands

181. Match the source gland with its respectively hormone as well as the function [NCERT; CBSE PMT (Pre.) 2011; NEET 2013]

Source gland	Hormone	Function
(a) Thyroid	Thyroxine	Regulates blood calcium level
(b) Anterior pituitary	Oxytocin	Contraction of uterus muscles during child birth
(c) Posterior pituitary	Vasopressin	Stimulates reabsorption of water in the distal tubules in the nephron
(d) Corpus luteum	Estrogen	Supports pregnancy

182. Match the column I with column II and select the correct option

Column I	Column II
A. ANF	1. Regulates blood calcium levels
B. MSH	2. Decreases blood pressure
C. GIP	3. Pigmentation
D. TCT	4. Inhibits gastric secretion

[Kerala PMT 2011; MH CET 2015]

- (a) A-4, B-1, C-2, D-3 (b) A-2, B-1, C-4, D-3  
(c) A-4, B-1, C-3, D-2 (d) A-3, B-2, C-4, D-1  
(e) A-2, B-3, C-4, D-1

183. During menstruation the level of progesterone in blood is [DPMT 2003]

- (a) Low (b) High  
(c) Normal (d) Very high

184. Hormone prolactin was discovered by

- (a) Riddle (b) Hisaw  
(c) Leonard (d) Hisaw and Leonard

185. During pregnancy which of the following is secreted through urine of mother [NCERT; CPMT 1993; AIEEE Pharmacy 2003; MP PMT 2009, 11; WB JEE 2012]

Or

The persistence of corpus luteum during pregnancy is due to a hormone known as [MP PMT 2001]

- (a) Progesteron (b) Luteinizing hormone  
(c) FSH (d) Chorionic gonadotropin

186. When mammary glands of male develop similar to that of female, then this condition is known as

[Odisha JEE 2005; J & K CET 2010]

- (a) Gonochorism (b) Gynaecomastia  
(c) Feminism (d) Gynaecism

187. Select the correct matched pair [Kerala PMT 2011]

(a) Pineal gland	-	Does not influence menstrual cycle
(b) Corpus luteum	-	Secretes oxytocin
(c) Interstitial cells	-	Erythropoietic
(d) Cholecystokinin	-	Stimulates pancreatic enzyme secretions
(e) Thyroxine	-	Triiodothyronine

188. Diabetes mellitus is caused due to the deficiency of insulin which is secreted by [MP PMT 1992, 95, 98, 2001; CPMT 1996; RPMT 2001; Odisha JEE 2012]

- (a) Alpha cells (b) Beta cells  
(c) Pituitary (d) Thyroid

189. Which of the following statements are false/true

- A. Calcitonin regulates the metabolism of calcium  
B. Oxytocin stimulates contraction of uterine muscles during birth  
C. Grave's disease is caused by malfunctioning of adrenal gland  
D. ADH stimulates absorption of water and increase the urine productions [Kerala PMT 2007]

- (a) A and C are true ; B and D are false  
(b) A and B are true ; C and D are false  
(c) A and D are false ; B and C are true  
(d) A, B and C are true ; D only false  
(e) A only true ; B, C and D are false

190. Match the columns

Column-I	Column-II
A. Adrenaline	1. Anger, fear, danger, pain
B. Oestrogen	2. Attracting partners through sense of smell
C. Insulin	3. Females
D. Pheromones	4. Glucose

[Kerala CET 2003; AIIMS 2010]

A	B	C	D
(a) 3	1	4	2
(b) 1	3	2	4
(c) 1	3	4	2
(d) 3	1	2	4

191. The function of glucagon hormone is [MP PMT 2003]

- (a) To increase glycogenesis  
(b) To decrease blood sugar level  
(c) To release glucose from liver cells and glycogenolysis promotion  
(d) To increase the absorption of glucose and fatty acids through cell

192. Glucagon and insulin are

[Bihar MDAT 1995; AIEEE Pharmacy 2003]

- (a) Antagonistic secretions  
(b) Secreted by same cells and perform similar function  
(c) Secreted by different cells and perform antagonistic function  
(d) Secreted by same cells and perform antagonistic functions  
(e) None of the above

- 193.** Which one of the following hormone is antiinflammatory  
[MP PMT 1992]  
(a) Secretin (b) Epinephrin  
(c) Glucoprotein (d) Glucocorticoid
- 194.** An overdose of intravenous insulin may lead to the death of an individual due to  
[MP PMT 1992]  
(a) An excessive increase of blood glucose  
(b) An excessive decrease of blood glucose  
(c) An inhibition of glucagon secretion  
(d) An over production of histamine
- 195.** Pancreas secretes  
[RPMT 1995]  
(a) Digestive enzymes (b) Insulin  
(c) Glucagon (d) All the above
- 196.** Gluconeogenesis is controlled by  
[CPMT 1994]  
(a) Cortisol (b) Corticosterone  
(c) Thyroxine (d) All the above
- 197.** 'Mammalian thymus' is mainly concerned with  
[BHU 2006]  
(a) Regulation of body temperature  
(b) Regulation of body growth  
(c) Immunological functions  
(d) Secretion of thyrotropin
- 198.** The structure of insulin consists of two polypeptide chains A and B. These two polypeptide chains  
(a) Have equal number of amino acids  
(b) Chain A has 21 amino acids, while chain B has 30 amino acids  
(c) Chain A has 30 amino acids, while chain B has 21 amino acids  
(d) Chain A has 11 amino acids, while chain B has 40 amino acids
- 199.** Match column I (hormone) with column II (endocrine gland) and column III (function)
- |    | Column I    |    | Column II |      | Column III                           |
|----|-------------|----|-----------|------|--------------------------------------|
| 1. | Melatonin   | A. | Thyroid   | i.   | Acts on the renal tubules            |
| 2. | MSH         | B. | Adrenal   | ii.  | Regulates blood calcium levels       |
| 3. | Aldosterone | C. | Pituitary | iii. | Maintains diurnal rhythm of our body |
| 4. | TCT         | D. | Pineal    | iv.  | Acts on the melanocytes              |
- [Kerala PMT 2012]  
(a) 4-A-iv; 3-D-iii; 1-B-ii; 2-C-i  
(b) 1-D-iii; 2-C-iv; 3-B-i; 4-A-ii  
(c) 1-B-i, 4-A-iii, 3-C-ii, 2-D-iv  
(d) 2-D-ii, 1-B-i; 4-C-iv; 3-C-iii  
(e) 2-C-iv; 3-A-ii; 1-D-iii; 4-B-i
- 200.** Which of the following hormones is responsible for hoarseness in voice, beard, moustaches etc. in males  
[CPMT 1995]  
(a) Gonadotropic hormone (b) Adrenaline  
(c) Thyroid (d) All the above
- 201.** Which hormone(s) of the following endocrine glands lacks peptides, amines and sulphur  
[AFMC 1995]  
(a) Hormone of anterior pituitary  
(b) Hormone of posterior pituitary and pancreas  
(c) Hormone of thyroid and adrenal gland  
(d) Hormone of testes and ovary
- 202.** With reference to the pituitary, which of the following statements is true  
[KCET 2011]  
(a) Neurohypophysis secretes vasopressin and oxytocin  
(b) Neurohypophysis secretes TSH and STH  
(c) Neurohypophysis collects and stores vasopressin and oxytocin  
(d) Adenohypophysis secretes vasopressin and oxytocin
- 203.** Progesterone is a  
[RPMT 1995]  
(a) Carbohydrate (b) Steroid  
(c) Protein (d) Sterol
- 204.** Low  $\text{Ca}^{++}$  in the body fluid may be the cause of  
[CBSE PMT (Pre.) 2010]  
(a) Gout (b) Tetany  
(c) Anaemia (d) Angina pectoris
- 205.** Gorilla like man with large head and hands and protruding jaws, is produced due to  
[MP PMT 1997]  
(a) Over secretion of thyroxine  
(b) Over secretion of growth hormone since maturity  
(c) Excess of vitamin 'C' in diet  
(d) Excess secretion of TSH
- 206.** In males, the essential hormone for secondary sexual characteristics is  
[MP PMT 1999]  
Or  
The hormone which brings about characteristic changes in the male at puberty is called  
(a) Testosterone (b) Progesterone  
(c) Estrogen (d) Relaxin
- 207.** The adrenal cortex synthesizes only  
[WB JEE 2016]  
(a) Steroid hormones (b) Peptide hormones  
(c) Glycopeptide hormones (d) Catecholamines
- 208.** The posterior pituitary gland is not a 'true' endocrine gland because  
[NEET (Phase-II) 2016]  
(a) It secretes enzymes  
(b) It is provided with a duct  
(c) It only stores and releases hormones  
(d) It is under the regulation of hypothalamus
- 209.** GnRH, a hypothalamic hormone, needed in reproduction, acts on  
[NEET 2017]  
(a) Anterior pituitary gland and stimulates secretion of LH and oxytocin  
(b) Anterior pituitary gland and stimulates secretion of LH and FSH  
(c) Posterior pituitary gland and stimulates secretion of oxytocin and FSH  
(d) Posterior pituitary gland and stimulates secretion of LH and relaxin

# N Q NCERT

## Exemplar Questions

1. Select the right match of endocrine gland and their hormones among the options given below
- |                    |                        |
|--------------------|------------------------|
| A. Pineal          | i. Epinephrine         |
| B. Thyroid         | ii. Melatonin          |
| C. Ovary           | iii. Estrogen          |
| D. Adrenal medulla | iv. Tetraiodothyronine |
- Options  
(a) A-iv, B-ii, C-iii, D-i  
(b) A-ii, B-iv, C-i, D-iii  
(c) A-iv, B-ii, C-i, D-iii  
(d) A-ii, B-iv, C-iii, D-i
- [NCERT]

2. Listed below are the hormones of anterior pituitary origin. Tick the wrong entry [NCERT]
- Growth hormone
  - Follicle stimulating hormone
  - Oxytocin
  - Adrenocorticotrophic hormone
3. Mary is about to face an interview. But during the first five minutes before the interview she experiences sweating, increased rate of heart beat, respiration etc. Which hormone is responsible for her restlessness [NCERT]
- Estrogen and progesterone
  - Oxytocin and vasopressin
  - Adrenaline and noradrenaline
  - Insulin and glucagons
4. The steroid responsible for balance of water and electrolytes in our body is [NCERT]
- Insulin
  - Melatonin
  - Testosterone
  - Aldosterone
5. Thymosin is responsible for [NCERT]
- Raising the blood sugar level
  - Raising the blood calcium level
  - Increased production of T lymphocytes
  - Decrease in blood RBC
6. One of the following conditions is not linked to deficiency of thyroid hormones [NCERT]
- Cretinism
  - Goitre
  - Myxoedema
  - Exophthalmosis
7. Cortisol is secreted from [NCERT]
- Pancrease
  - Thyroid
  - Adrenal
  - Thymus
8. Hormones are called chemical signals that stimulate specific target tissues. Their specificity is due to the presence of signal receiving 'receptors' only in the respective target tissues. Where are these receptors present in case of hormones of protein nature [NCERT]
- Extra cellular matrix
  - Blood
  - Plasma membrane
  - Nucleus
9. Choose the correct answer among the following options
- |                              |   |
|------------------------------|---|
| A. Epinephrine               | i. Increase in muscle growth            |
| B. Testosterone              | ii. Decrease in blood pressure          |
| C. Glucagon                  | iii. Decrease in liver glycogen content |
| D. Atrial natriuretic factor | iv. Increase heart beat                 |
- Options: [NCERT]
- A-ii, B-i, C-iii, D-iv
  - A-iv, B-i, C-iii, D-ii
  - A-i, B-ii, C-iii, D-iv
  - A-i, B-iv, C-ii, D-iii
10. Blood calcium level is a resultant of how much dietary calcium is absorbed, how much calcium is lost in the urine, how much bone dissolves releasing calcium into the blood and how much calcium from blood enters tissues. A number of factors play an important role in these processes. Mark the one which has no role [NCERT]
- Vitamin D
  - Parathyroid hormone
  - Thyrocalcitonin
  - Thymosin
11. All the following tissues in mammals except one consists of a central 'medullary' region surrounded by a cortical region. Mark the wrong entry [NCERT]
- Ovary
  - Adrenal
  - Liver
  - Kidney



## Critical Thinking

## Objective Questions

1. In an accident the anterior pituitary of a four year old boy was severely damaged but the boy survived. What is likely to happen [MP PMT 1992]
- High levels of thyroxin will be released
  - Spermatogenesis will be stimulated
  - The boy will not grow much in height
  - The growth of mammary glands will be stimulated
2. Which one of the following hormones inhibits gastric secretion [CPMT 1992, 93]
- Gastrin
  - Secretin
  - Enterogastrone
  - Cholecystokinin
3. Feeling the tremors of an earthquake a scared resident of seventh floor of a multistorey building starts climbing down the stairs rapidly. Which hormone initiated this action [CBSE PMT 2007]

Or

Injury to adrenal cortex is not likely to affect the secretion of which one of the following [CBSE PMT (Pre.) 2010]

- Thyroxin
  - Adrenaline
  - Glucagon
  - Gastrin
4. The correct set of a single endocrine gland hormone is
- Oxytocin, prolactin, ACTH
  - Oxytocin, vasopressin, ADH
  - Thyroxin, secretin, ACTH
  - Epinephrin, cortisol, ICSH
5. Which of the following is an emergency hormone [NCERT; CPMT 1995, 2000; AIIMS 2000; AFMC 2001; MH CET 2003; BHU 2006; MP PMT 2013]

Or

When an animal is angry and wants to fight, the hormone that is secreted is

- Pituitary
  - Prolactin
  - Progesterone
  - Adrenalin
6. Appearance of facial hairs in a woman may be due to the effect of [MP PMT 1992]
- Temperature
  - Ultraviolet radiation
  - Hormone
  - Pollution
7. Thyroxine is [MP PMT 1998; BVP 2000]
- An enzyme
  - A hormone
  - A vitamin
  - An excretory product
8. If thyroid gland is completely removed from a tadpole, it will [MP PMT 2001]
- Die immediately
  - Turn into a giant frog
  - Turn into a dwarf frog
  - Remain tadpole throughout its life
9. Which one of the following is an example of negative feedback loop in humans [CBSE PMT 2007]
- Constriction of skin blood vessels and contraction of skeletal muscles when it is too cold
  - Secretion of tears after falling of sand particles into the eye
  - Salivation of mouth at the sight of delicious food
  - Secretion of sweat glands and constriction of skin blood vessels when it is too hot

10. In the homeostatic control of blood sugar level, which organs function respectively as modulator and effector  
[KCET 2006]  
(a) Liver and islets of langerhans  
(b) Hypothalamus and liver  
(c) Hypothalamus and islets of langerhans  
(d) Islets of langerhans and hypothalamus
11. The urine of a man is very dilute and the quantity of urine is too much and dehydration has started in his body and he is very thirsty by the cause of  
[CPMT 1994]  
(a) Hypersecretion of ADH (b) Hyposecretion of ADH  
(c) Both (a) and (b) (d) None of the above
12. Which of the following pair of hormones is responsible for the growth and maturation of the graafian follicle  
[MP PMT 1995; BHU 2006]  
(a) GH-ADH (b) ACTH-LH  
(c) FSH-LH (d) FSH-LTH
13. FSH and LH hormones together are called  
[MP PMT 1997, 2002; CPMT 2000; HPMT 2005]  
(a) Emergency hormones (b) Gonadotropic hormones  
(c) Neurohormones (d) Outstress hormones
14. Secretion of progesterone by corpus luteum is initiated by  
[CBSE PMT 1999]  
(a) MSH (b) LH  
(c) Testosterone (d) Thyroxine
15. Which hormone promotes cell division, protein synthesis and bone growth  
[AFMC 1999; BVP 2000; RPMT 2002]  
(a) GH (STH) (b) PTH  
(c) ADH (d) ACTH
16. Function of hypothalamus is  
[RPMT 1995]  
(a) Helps in sleeping (b) Related to hunger and thirst  
(c) Temperature regulation (d) All the above
17. Which of the following is both (mixed) exo and endocrine gland  
[AFMC 2000; RPMT 2001; MP PMT 2002; Odisha JEE 2012]  
(a) Thyroid (b) Pancreas  
(c) Payer's patches (d) Thymus
18. Which endocrine gland becomes inactive in old age  
[MP PMT 1999; DPMT 2006]  
(a) Adrenal (b) Pineal  
(c) Thymus (d) Pituitary
19. Which of the following is an accumulation and release centre of neurohormones  
[CBSE PMT 2006]  
(a) Hypothalamus  
(b) Anterior pituitary lobe  
(c) Posterior pituitary lobe  
(d) Intermediate lobe of the pituitary
20. Which of the following is not secreted by pituitary gland  
[RPMT 1995]  
(a) ACTH (b) GH  
(c) FSH (d) Thyroxine
21. A man has an I.Q. equivalent to that of a boy 5 years old, this is due to deficiency of which hormone  
[CPMT 1996]  
(a) Thyroxine (b) Adrenaline  
(c) Aldosterone (d) Somatotropin
22. Hypersecretion of Growth Hormone in adults does not cause further increase in height, because  
[NEET 2017]  
(a) Growth Hormone becomes inactive in adults  
(b) Epiphyseal plates close after adolescence  
(c) Bones loose their sensitivity of Growth Hormone in adults  
(d) Muscle fibres do not grow in size after birth

## R Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

- (a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion  
(b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion  
(c) If the assertion is true but the reason is false  
(d) If both the assertion and reason are false  
(e) If the assertion is false but reason is true
1. Assertion : Diabetes insipidus is marked by excessive urination and too much thirst of water.  
Reason : Anti-diuretic hormone (ADH) is secreted by the posterior lobe of pituitary.  
[AIIMS 2008]
2. Assertion : Adrenal cortex can be removed without causing death.  
Reason : Adrenal cortex is not vital for survival.
3. Assertion : Adrenal cortex is called the gland for 'fight, fright and flight'.  
Reason : The hormones adrenaline and noradrenaline help the body to combat against stress and emergency conditions.
4. Assertion : FSH is also known as interstitial cell stimulating hormone.  
Reason : It is because of the fact that FSH stimulates the interstitial cells of testis.
5. Assertion : Failure of secretion of somatotropin from an early age causes dwarfism in the patient.  
Reason : Somatotropin hormone stimulates the body growth and elongation of long bones.
6. Assertion : A tumor of adrenal cortex may cause addison's disease.  
Reason : This happens due to over secretion of cortisol by the tumor.
7. Assertion : Oxytocin is also known as Anti Diuretic hormone (ADH).  
Reason : Oxytocin can cause an increase in the renal reabsorption of water.
8. Assertion : Prolactin is also called the 'Milk ejection hormone'.  
Reason : Prolactin stimulates the smooth muscle contractions of the mammary glands.
9. Assertion : The tadpoles become giant tadpoles when fed on thiourea.  
Reason : Thiourea is an antithyroid substance.
10. Assertion : Females have less stature than males after puberty.  
Reason : This happens because of the presence of HCG in the blood of females.

# Answers

## Hormones and their mechanism

1	b	2	d	3	c	4	b	5	c
6	d	7	a	8	b	9	d	10	c
11	b	12	c	13	d	14	c	15	b
16	b	17	c	18	d	19	d	20	a
21	c	22	c						

## Different glands and their hormones

1	b	2	d	3	d	4	b	5	c
6	a	7	a	8	a	9	b	10	b
11	c	12	d	13	a	14	b	15	a
16	c	17	c	18	d	19	c	20	c
21	d	22	c	23	d	24	b	25	b
26	c	27	c	28	d	29	d	30	b
31	c	32	b	33	b	34	a	35	a
36	b	37	a	38	c	39	b	40	c
41	d	42	b	43	a	44	d	45	a
46	a	47	a	48	a	49	b	50	c
51	a	52	d	53	a	54	a	55	c
56	a	57	b	58	d	59	d	60	d
61	c	62	d	63	c	64	a	65	c
66	d	67	d	68	b	69	a	70	a
71	a	72	c	73	a	74	a	75	b
76	d	77	b	78	b	79	d	80	b
81	b	82	d	83	a	84	a	85	c
86	a	87	b	88	b	89	a	90	b
91	c	92	a	93	a	94	d	95	a
96	d	97	c	98	d	99	a	100	c
101	a	102	b	103	a	104	a	105	c
106	d	107	d	108	b	109	d	110	b
111	b	112	d	113	a	114	d	115	c
116	c	117	d	118	b	119	a	120	a
121	d	122	d	123	a	124	b	125	b
126	b	127	d	128	c	129	d	130	b
131	a	132	c	133	b	134	a	135	a
136	a	137	c	138	b	139	d	140	d
141	c	142	b	143	c	144	a	145	a
146	c	147	d	148	a	149	a	150	a

151	d	152	d	153	b	154	a	155	b
156	a	157	b	158	b	159	b	160	a
161	b	162	c	163	d	164	c	165	e
166	c	167	a	168	c	169	b	170	c
171	a	172	a	173	a	174	a	175	a
176	c	177	b	178	a	179	b	180	a
181	c	182	e	183	a	184	d	185	d
186	b	187	d	188	b	189	b	190	c
191	c	192	c	193	d	194	b	195	d
196	d	197	c	198	b	199	b	200	a
201	d	202	c	203	b	204	b	205	b
206	a	207	a	208	c	209	b		

## NCERT Exemplar Questions

1	d	2	c	3	c	4	d	5	c
6	d	7	c	8	c	9	b	10	d
11	a								

## Critical Thinking Questions

1	c	2	c	3	b	4	b	5	d
6	c	7	b	8	d	9	d	10	c
11	b	12	c	13	b	14	b	15	a
16	d	17	b	18	c	19	a	20	d
21	a	22	b						

## Assertion and Reason

1	b	2	d	3	e	4	d	5	a
6	d	7	d	8	d	9	a	10	c

# Answers and Solutions

## Hormones and their mechanism

- (b) Cyclic AMP and GMP act as intracellular mediators and affect the cell metabolism in various ways. According to the second messenger theory given by Sutherland the 1<sup>st</sup> messenger is hormone itself and the 2<sup>nd</sup> messenger is cyclic AMP.
- (c) Hormone is a chemical messenger produced by endocrine glands and secreted directly into the blood stream to exert a specific effect on a distant part of the body.
- (a) Kupffer's cells occur in the lining of liver sinusoids and help in phagocytosis.
- (d) Hormone do not belong to a single chemical group but are varied in their composition is polypeptide, proteins, amines or steroid

11. (b) Pheromones serve to conduct messages by smell and taste and affect the mutual behaviour of members of a species.
13. (d) The father of endocrinology is Thomas Addison. The first endocrine disease reported was Addison's disease caused by destruction of adrenal cortex.
14. (c) Starling (1905) first used the term hormone for internal secretion.
15. (b) The molecules of amino acid derivatives, peptides or polypeptide (protein) hormones bind to specific receptor molecules located on the plasma membrane of target cells.
17. (c) Inositoltriphosphate ( $IP_3$ ) & diacylglycerol (DAG) act as intracellular secondary messengers responsible for amplification of signal.  $IP_3$ , being water soluble, diffuses in the cytoplasm to stimulate the release of  $Ca^{+2}$  from endoplasmic reticulum of target cells. The latter activate many  $Ca^{+2}$  mediated reactions. DAG remains in the cell membrane to activate the enzyme protein kinase - C. Certain body cells use more than one secondary messenger, e.g. in heart cells, c-AMP acts as a secondary messenger to stimulate the release of  $Ca^{2+}$  from sarcoplasmic reticulum of muscle fibre resulting in muscle contraction.  
Phospholipase is any of various enzymes that cleave particular bonds in the polar phosphate 'heads' of glycerophospholipids
18. (d) Hormones composition can be polypeptide proteins, amines or steroid.
20. (a) Endocrine glands are ductless gland their secretion flows directly into the blood stream.
21. (d) Cortisol and testosterone are steroid group of hormones which bind to intracellular receptor.
22. (c) MSH increases skin pigmentation by stimulating the dispersion of melanin granules in melanocytes. Since it affects the target cells directly i.e. it affect the distribution of melanin granules in the chromatophores/melanocytes directly.
25. (b) Vasopressin decreases loss of water through urine. Glucagon is released from  $\alpha$  - cells. Prolactin is released from anterior pituitary.
27. (c) Endemic goitre is due to low iodine in soil and water in hilly areas.
29. (d) The hyposecretion of GH in the adult life lead to a rare condition called "simmond's disease" The patient becomes quite thin and shows signs of premature ageing.
34. (a) At the dorsal surface of diencephalon.
36. (b) Follicular stimulating hormone (FSH) is glycoprotein in nature.
38. (c) The gonadotrophic hormones (FSH and ICSH (= LH) are secreted by anterior lobe of the pituitary (adenohypophysis).
39. (b) Hypothalamus regulates body temperature.
43. (a) In pregnant female, hCG maintains the corpus luteum which secretes estrogen and progesterone.
45. (a) Basophil cells of *pars distalis* or anterior pituitary secrete luteinizing hormone which is responsible for maintenance of corpus luteum.
46. (a) Pitressin is also called as ADH or vasopressin.
54. (a) In fight or flight reactions, emergency hormones are secreted by adrenal medulla
56. (a) Hypothalamus cells are also known to synthesize two more hormones : oxytocin and vasopressin which are stored in their axons extending in the posterior lobe of pituitary gland.
57. (b) Vasopressin reduces the excretion of water in urine by promoting its reabsorption from DCT. When vasopressin is released in lesser amounts, diuresis increases.
60. (d) Neurosecretory cells of hypothalamus secrete neurohormones called thyrotrophic releasing factors (TRF) or inhibiting factor (IF).
62. (d) Calcitonin is a noniodinized hormone secreted by the parafollicular cells (clear or cells) of thyroid stroma.
64. (a) Simple goitre is caused by lower intake of iodine through diet, goitre is the swelling of neck due to enlargement of thyroid.
65. (c) Myxoedema occurs due to deficiency of thyroxine in adult. The peculiar feature of myxoedema is that face and hand become swollen due to deposition of albuminous myxomatous tissue.
66. (d) Acromegaly characterised by abnormal elongation of limbs and lower jaw, giving gorilla like appearance and kyphosis protruding bony ridge over the eyes. It occurs due to oversecretion of STH in adult.
67. (d) Hyposecretion of thyroxine during the growing years of birth is called childhood hypothyroidism or cretinism. Two important symptoms are dwarfism and mental retardation also.

### Different glands and their hormones

2. (d) Deficiency of somatotrophic hormone (STH) from early age result in growth of long bones and of the body stops prematurely making the patient Dwarf
5. (c) Myxoedema occurs due to deficiency of thyroxine in adults. It is characterized by low BMR, low body temperature, reduced heart rate, pulse rate, cardiac output, Face and hands become swollen.
7. (a) Aldosterone is secreted by adrenal cortex and is responsible for regulation of  $Na^+$  and  $K^+$  levels in body.
8. a) Both are neurohypophyseal hormones and ADH is the only other name for vasopressin.
12. (d) In the male, ICSH stimulates the interstitial cells of leydig in testis to develop and secrete large amount of testosterone.
13. (a) In male, FSH stimulates the testis to initiate sperm production.
16. (c) Failure of secretion of vasopressin leads to a reduced renal reabsorption of water and a consequent elimination of a large volume of very dilute urine this disorder is known as diabetes insipidus.
18. (d) ADH and oxytocin are secreted by hypothalamus and stored in posterior pituitary.
19. (c) Hypoparathyroidism results in hypocalcemia. Skeletal muscles fail to relax causing tetany and hyperparathyroidism result in osteoporosis i.e. dissolution of bone and hypercalcemia.



68. (b) Exophthalmic goitre (Grave's disease) is hyperthyroidism. Eye balls protrude due to accumulation of mucus in eye orbits metabolic rate is abnormally high.
82. (d) Thyroid gland is made up of tiny follicles (hollow spheres whose wall is singly layered cuboidal epithelium). In these follicles, thyroid hormones are stored, and bound to a protein called thyroglobulin formed by the follicle. To release the hormones into the blood, the epithelial cells take up thyroglobulin by pinocytosis and remove the active hormone from thyroglobulin.
83. (a) Iodine is used by thyroid gland for the synthesis of thyroid hormone. Thus radio active isotope iodine - 131 is used as radioactive material for detection of thyroid cancer.
89. (a) Iodine is essential for the synthesis of thyroid hormones. An adult human body contains about 5 to 6mg of iodine and most of it is found in thyroid gland. Thyroxine is iodine containing amine hormone which is derived from tyrosine amino acid and secreted by thyroid gland.
90. (b) The most important function of thyroid hormone is to enhance the basal metabolic rate in our body. They are secreted by thyroid gland.
94. (d) Thyroid initiate, regulates and plays a key role in the metamorphosis of frog's tadpole. The changes that takes place during transformation of larva into adult are called as metamorphosis.
101. (a) Parathormone is secreted by parathyroid gland. It is also called as parathymin. It controls calcium levels in blood plasma and metabolism.
106. (d) Contraceptive pills for women contain female sex hormones oestrogen and progesterone. These prevent development of eggs and ovulation by inhibiting secretion of FSH some pills contain progesterone only in such cases ovulation may occur but cervical mucus is thickened preventing the entry of sperm.
112. (d) Mineralocorticoids hormones are 21-carbon steroids secreted by the cells of zona glomerulosa of adrenal cortex. The principal mineralcorticoid is aldosterone. It is a salt retaining hormone". It upgrades sodium ion concentration in the ECF by promoting reabsorption of sodium ions from renal tubules and excretion of potassium ions in urine. Conn's disease is characterised by rise in blood volume and pressure and is caused due to over secretion of aldosterone.
113. (a) The endocrine part of testes is formed of groups of cells, called Interstitial cell or Leydig's cells. Leydig's cells of testes are stimulated to secrete male sex hormones called, androgen.
116. (c) Progesterone, Testosterone and Oestrogen these are the hormones of gonads. But the adrenalin is the hormone of adrenal medulla.
120. (a) Hyposecretion of glucocorticoids which are a hormone of adrenal cortex results in Addison's disease.
124. (b) Because adrenal medulla is a modified sympathetic ganglion of autonomic nervous system. It develops from same embryonic tissue as all other sympathetic ganglia develop.
127. (d) Adrenal glands are paired endocrine glands located superior to kidney, hence called 'suprarenals'.
133. (b) Glucagon is secreted by  $\alpha$ -cells of pancreatic islets.
136. (a) Life-saving hormones are secreted by adrenals. An increased output of cortisol is actually "life saving in shock condition".
137. (c) Adrenalin increases the rate of heart beat and cardiac output, so increases blood pressure.
138. (b) Epinephrine hormones are amine hormones and are derivatives of catechol, so collectively called catecholamines.
139. (d) Glucagon is a hyperglycaemic or diabetogenic polypeptide hormone secreted by  $\alpha$ -cells of islets of Langerhans. Its secretion is stimulated by low blood sugar level.
140. (d) Medulla of adrenal secretes nor-epinephrin/adrenalin hormone which is sympathomimetic.
141. (c) Aldosterone hormone of the adrenal cortex is also called salt retaining hormone. Increased sodium concentration increases salt concentration of interstitial fluid which increases water reabsorption.
143. (c) Hassall's corpuscles are spherical or oval bodies present in the thymus. They are phagocytic in function.
145. (a) Pineal gland is an endocrine organ, it is located on the roof of diencephalon.
146. (c) Pineal body was considered vestigial of 3<sup>rd</sup> eye earlier but now has been confirmed to be endocrine gland.
147. (d) Pineal gland secretes three hormones namely melatonin, serotonin and adrenoglomerulotropin.
149. (a) The hormone oxytocin is sometimes used to hasten the child birth. It contracts the involuntary smooth muscles of the uterus to expel the child.
152. (d) Called Sertoli cells.
154. (a) Sucking at nipple causes reflexes to release oxytocin hormone from the posterior pituitary gland which in turn causes the contraction of breast alveoli and secretion of milk. Prolactin another hormone is responsible for production of milk not its secretion.
155. (b) Oxytocin causes contraction of the smooth muscles of myometrium forcing the foetus out of the uterus. Oxytocin is also involved in ejection of milk, but not lactation (actual production of milk) for milk to be produced, prolactin must be present.
156. (a) Progesterone is a principal female sex hormone. It is a steroid. It is secreted during the later half of the menstrual cycle in human female by temporary endocrine tissue, the corpus luteum. The luteinizing hormone (LH) of anterior pituitary brings about a rupture of the graafian follicle to release the ovum, and changes the ruptured follicle into a yellow structure called corpus luteum, which secretes progesterone.
158. (b) Progesterone a hormone produced by mammalian corpus luteum maintains pregnancy. It is responsible for the implantation of embryo and formation of uterine bed and placenta, as well as for inhibiting of ovulation and action of oxytocin on uterus during pregnancy.
160. (a) The molecules of hormones that are amino acid derivatives, peptides or proteins are large and insoluble in lipids, and cannot enter the target cell. Therefore, they act at the cell surface. They bind to specific receptor molecules located on the surface of the cell membrane. Insulin is a polypeptide hormone, so it operates through extracellular membrane bound receptor, a heterotetrameric protein (extrinsic protein) on the target cell.

161. (b) Melatonin, secreted by the pineal gland, stimulates the concentration of pigment granules in the melanocytes, lightening the skin colour.
162. (c) A temporary structure with endocrine function is placenta.
164. (c) It increases width of vaginal passage by relaxing pelvic ligaments there by helps in parturition i.e. child birth.
166. (c) It increases synthesis and secretion of milk.
167. (a) Pancreas is a heterocrine gland. The endocrine part is formed of about 1 to 2 million groups of epithelial cells, called islets of Langerhans.
171. (a) High sugar level in blood is called hyperglycemia.
175. (a) Relaxin is a proteinous hormone secreted by the corpus albicans formed from the corpus luteum at the end of gestation period. It softens the pubic symphysis so help in parturition (child birth).
176. (c) Banting and Best (1921) extracted insulin from pancreas and showed that it reduces blood sugar in dogs.
177. (b) A. Ovary secretes oestrogen for maintenance of secondary sexual characters.  
B. Alpha cells of Islets of Langerhans secrete glucagon which raises blood sugar level.  
C. Anterior lobe of pituitary secretes growth hormone. Its over secretion leads to gigantism.
181. (c) Vasopressin (ADH) is synthesised in hypothalamus but released into the blood from posterior lobe of pituitary, so it is called as a hormone of posterior lobe. It stimulates reabsorption of water in distal tubules in the nephron.
185. (d) Its presence in urine confirms pregnancy, therefore used for pregnancy test.
186. (b) Excessive secretion of female hormones in adult males may cause enlarged mammary gland (Gynaecomastia) and retards growth of breast.
188. (b) Beta cells of islets of Langerhans.
192. (c) Glucagon is antagonistic to insulin. Antagonistic hormones are those which work against each others. Glucagon increases sugar level in blood and insulin decreases glucose level in blood.
193. (d) Glucocorticoids include three main hormones : cortisol, corticosterone and cortisone. Cortisone has anti insulin effect. It also helps in reducing pain cortisol is anti-inflammatory.
194. (b) Oral dose of insulin is degenerated by the hydrolysing action of enzymes in the stomach.
195. (d) Pancreas is a heterocrine gland which secretes both enzyme and hormone.
197. (c) 'Mammalian thymus' is a bilobed lymphoid organ situated in front of the heart in the upper part of sternum.
198. (b) Chemically insulin is a protein (large polypeptide) Insulin contains 51 amino acid arranged in two chain, an acidic A chain containing 21 amino acid residues and a basic B-chain containing 30 residue.
201. (d) Hormones produced by gonads i.e. testis and ovary are steroid in chemical nature i.e. they are derived from fats.
203. (b) Chemical nature of progesterone is steroid (cholesterol) i.e. derived from fats.
205. (b) The hypersecretion during adulthood is called acromegaly (after the closure of the epiphyseal plates at the ends of the bones) Acromegaly patient has a gorilla-like appearance with huge hand and legs.
206. (a) Testosterone stimulates the development of male secondary sexual characters like-beard, moustaches, deepening of voice, broadening of shoulders, increased height due to elongation of bones and increased development of limbs.
207. (a) All hormones of adrenal cortex are steroid in nature and are derived from cholesterol.

### Critical Thinking Questions

2. (c) Enterogasterone is secreted by the epithelium which inhibits gastric secretion and motility.
4. (b) Oxytocin and ADH is secreted from posterior pituitary, vasopressin is another name of ADH.
5. (d) Adrenaline whip up metabolism to prepare animal to face special physical or mental stress. This cause contraction of spleen to squeeze out the reserve blood as well as stimulate the breakdown of liver and muscle glycogen to provide more glucose for respiration.
8. (d) Because thyroid gland helps in tissue differentiation and hence, in metamorphosis.
11. (b) Due to deficiency of ADH water absorption by kidney tubules is decreased leading to excessive urine formation i.e. diuresis, so the person feels thirsty due to dehydration.
13. (b) FSH and LH are collectively known as gonadotropic hormone because they regulate the growth and functioning of gonads.
15. (a) The chief function of STH (GH) is to promote synthesis and secretion of small protein hormone called insulin like growth factors (IGFs).
17. (b) Pancreas is a mixed gland (heterocrine gland) with both exocrine and endocrine portion.
18. (c) Thymus is well developed in new born child and grows upto the age of puberty after that it starts shrinking and almost disappears in old age.
20. (d) Thyroxine is secreted by thyroid gland.
21. (a) Thyroxine causes the development and differentiation of brain.

### Assertion and Reason

1. (b)
2. (d) Adrenals or suprarenals are two conical pyramid shaped glands, one immediately above each kidney. Each adrenal is made up of an outer layer called adrenal cortex and a central portion called adrenal medulla. The cortex and the medulla secrete different hormones and are regulated in different ways. Adrenal cortex is vitally important for life because it secretes a number of steroid hormones belonging to three broad groups viz. glucocorticoids, mineralocorticoids and sex corticoids. Hence its destruction or removal kills the animal. On the other hand, Adrenal medulla is not vital for survival and may be removed without causing death. Adrenal medulla helps the body to combat against stress or emergency conditions by secreting two hormones viz. adrenaline and noradrenaline.

3. (e) It is not the adrenal cortex but the adrenal medulla which is also called the gland for 'fight, fright and flight', because the hormones secreted by adrenal medulla viz. adrenaline and noradrenaline helps the body to combat against stress or emergency conditions. Adrenaline or epinephrine dilates (widens) arterioles in the skeletal muscles and constricts (narrows) those in the skin and abdominal viscera. It increases the rate and force of heart beats and arterial blood pressure by enhancing the cardiac output. Adrenaline relaxes the smooth muscles of gastro-intestinal tract, and urinary bladder and bronchioles and contracts the sphincters of gastrointestinal tract and bladder.

Increases blood sugar and blood lactic acid levels and also increases heat production, metabolic rate and body temperature. Noradrenaline or norepinephrine constricts arterioles in general or increase the total peripheral resistance against the flow of blood. The coordinated actions of both adrenaline and noradrenaline, thus help the body to react under stress conditions.

4. (d) It is not FSH (follicle stimulating hormone), but the LH (lutelizing hormone) which is also known as Interstitial Cell Stimulating Hormone (ICSH). It stimulates the interstitial cells of leydig, of testis to secrete the male sex hormone testosterone and other androgen to regulate the secondary sexual characteristics.

The follicle stimulating hormone (FSH) is secreted by anterior pituitary. It stimulates the testes in the males to produce sperms and the ovaries in the female to produce ova. It also stimulates ovaries to secrete female sex hormones called oestrogens.

5. (a) The somatotropin (STH), also called growth hormone (GH) is secreted by the anterior lobe of pituitary gland. Somatotropin stimulates body growth by stimulating retention of proteins and calcium in the body, synthesis and deposition of proteins in tissues, growth and elongation of long bones, and proportionate growth of muscles and visceral organs. The failure of secretion of growth hormone from an early age stops the growth of long bones and of the body prematurely; this makes the patient dwarf and this condition is called dwarfism.

6. (d) A destruction of adrenal cortex by diseases like tuberculosis produces Addison's disease, due to the deficiency of glucocorticoids and mineralocorticoids which are secreted by the adrenal cortex region zona fasciculata and zona glomerulosa respectively. Symptoms of Addison's disease include a bronze-like pigmentation of skin, low blood sugar, low plasma  $\text{Na}^+$ , high plasma  $\text{K}^+$ , increased urinary  $\text{Na}^+$ , nausea, vomiting and diarrhoea.

Cortisol is a glucocorticoid which regulates the metabolisms of carbohydrates, fats and proteins. A tumor of the adrenal cortex may secrete too much cortisol to produce Cushing's syndrome.

High blood sugar, appearance of sugar in the urine, obesity, wasting of limb muscles, rise in plasma  $\text{Na}^+$ , fall in plasma  $\text{K}^+$ , rise in blood volume and high blood pressure are observed in the patient suffering from Cushing's syndrome.

7. (d) It is not oxytocin, but the hormone vasopressin (also known as antidiuretic hormone, ADH) because it reduces the volume of urine by increasing the reabsorption of water from the urine in the distal convoluted tubules, collecting tubules and collecting ducts in the kidney.

It does so by rendering the walls of those tubules permeable to water. Failure of secretion of vasopressin leads to a reduced renal reabsorption of water and a consequent elimination of a large volume of very dilute (hypotonic) urine. Oxytocin is another hormone released by the posterior lobe of pituitary gland. Oxytocin contracts the mammary glands, smooth muscles of uterus. Uterine contractions, stimulated by oxytocin at the end of pregnancy, help in the child-birth or parturition, hence also called birth hormone.

8. (d) It is not prolactin but oxytocin hormone also known as 'milk ejection hormone' because the oxytocin induces contractions of the mammary gland muscles help in the flow of stored milk from the mammary glands to the mouth of the suckling infant. Oxytocin contracts the smooth muscles of uterus and mammary glands. Uterine contractions, stimulated by oxytocin at the end of pregnancy, help in the child-birth. That is why, it is also called 'Birth hormone'.

Prolactin or lactogenic hormone or luteotrophic hormone (LTH) is secreted by the anterior pituitary which helps in the growth of mammary glands during pregnancy and initiates the secretion of milk after child-birth.

9. (a) The thyroid gland secretes thyroxine and triiodothyronine hormone. One of their function is stimulation of tissue differentiation. Because of this action, they promote metamorphosis of tadpoles into adult frogs. Feeding of anti-thyroid substances like thiourea to tadpoles, delays their metamorphosis. As they continue to grow without metamorphosis, they become giant tadpoles.

10. (c) Males have more stature than females because of the action of male sex hormone-testosterone which is secreted by testis in males. Body starts secreting testosterone from the age of puberty. Its secretion is under the influence of Luteinising Hormone (LH) of the anterior lobe of pituitary gland. Testosterone controls the development of secondary sexual characters in males like hoarseness of voice, development of facial hairs, bone growth, calcium retention, closing of epiphysial cartilage. The total quantity of bone matrix increases. The pelvic outlet is narrowed and lengthened. The strength of the pelvic bones increases to carry more loads. That is why males have more stature than females after puberty when this hormone is present in the blood.

HCG (Human Chorionic Gonadotropin) is the hormone secreted by human placenta during pregnancy. HCG enlarges the corpus luteum in the mother's ovary and stimulates it to secrete progesterone.

## Chemical Co-ordination and Integration

## SET Self Evaluation Test

- The secretion of following anterior pituitary hormones is controlled by hypothalamus [MP PMT 1992]
  - Thyrotropin (TSH) and cortisol
  - Follicle stimulating hormone (FSH) and progesterone
  - Corticotropin (ACTH), growth hormone and vasopressin
  - Luteinizing hormone (LH), corticotropin (ACTH) and thyrotropin (TSH)
- Which of the following hormone is not steroid [CPMT 2009]
  - Androgen
  - Aldosterone
  - Testosterone
  - Vasopressin
- Hypersecretion of GH from pituitary in the adult causes a disease called [CPMT 2004; MH CET 2005; MP PMT 2009]
  - Gigantism
  - Acromegaly
  - Cushing's disease
  - Addison's disease
- The nervous control of pituitary secretion lies in
  - Infundibulum
  - Pituitary centre
  - Hypothalamus
  - Medulla oblongata
- The hormone responsible for the regulation of metabolism of calcium and phosphorus is secreted by [RPMT 1995]
  - Thyroid
  - Parathyroid and thyroid both
  - Thymus
  - Pancreas
- The hormone which controls the rate of body metabolism is [CBSE PMT 1993; RPMT 2006]
  - Thyroxin
  - Insulin
  - ACTH
  - HGH
- Hypothyroidism causes [DPMT 2007]
  - Myxedema
  - Cretinism
  - Both (a) and (b)
  - Exophthalmic goitre
- A person is having problems with calcium and phosphorus metabolism in his body. Which one of the following glands may not be functioning properly [CBSE PMT 2007]
  - Parathyroid
  - Parotid
  - Pancreas
  - Thyroid
- Epinephrine is
  - Nephrostomal part of mesoderm
  - Clusters of glomeruli in mammalian kidney
  - Hormone of the adrenal gland
  - Frontal lobe of nephridia
- A steroid hormone which regulates glucose metabolism is [CBSE PMT 2006]
 

Or

Excess of which of the following hormones causes Cushing's syndrome [AFMC 2009]

  - 11-deoxycorticosterone
  - Cortisone
  - Cortisol
  - Corticosterone
- Prostaglandins are [CPMT 2009]
  - Amino acid
  - Steroid
  - Fatty acid
  - Carbohydrate
- Which of the endocrine gland is mainly concerned with immunity in man [CPMT 1994; MP PMT 1994, 99; Odisha JEE 2010]
  - Parathyroid gland
  - Adrenal gland
  - Thymus gland
  - Posterior pituitary gland
- The pancreas secretes [MP PMT 2013]
  - Pancreozym
  - Angiotensin I
  - Somatostatin
  - Angiotensin II
- Column I lists the endocrine structure and column II lists the corresponding hormones. Match the two columns. Identify the correct option from those given
 

Column I	Column II
A. Hypothalamus	p. Relaxin
B. Anterior pituitary	q. Estrogen
C. Testis	r. FSH and LH
D. Ovary	s. Androgens
	t. Gonadotropin releasing hormone

[Pb PMT 2000; KCET 2000, 06; JIPMER 2001; BHU 2005; MP PMT 2012]

  - A=t, B=r, C=s, D=q
  - A=t, B=r, C=q, D=s
  - A=p, B=q, C=s, D=r
  - A=r, B=t, C=s, D=q
- Match the hormone in column I with their function in column II
 

Column I	Column II
A. FSH	1. Prepare endometrium for implantation
B. LH	2. Develops female secondary sexual characters
C. Progesterone	3. Contraction of uterine wall
D. Estrogen	4. Development of corpus luteum
	5. Maturation of graffian follicle

[Kerala PMT 2006]

  - A-5, B-4, C-1, D-2
  - A-4, B-5, C-2, D-1
  - A-4, B-3, C-2, D-5
  - A-5, B-1, C-2, D-4

## AS Answers and Solutions

1	d	2	d	3	b	4	c	5	b
6	a	7	c	8	a	9	c	10	c
11	c	12	c	13	c	14	a	15	a

- (d) Hypothalamus secretes both releasing and inhibitory hormones controlling the secretion of some anterior pituitary hormones (LH, ACTH, and TSH etc.)
- (b) Hypersecretion of growth hormones or somatotrophic hormone during adulthood causes acromegaly. Acromegaly patient has a gorilla like appearance with huge hands and legs.
- (c) Hypothalamus synthesizes and secretes certain specific chemicals called factors which pass to adenohypophysis to control secretion of its hormones, thereby called master of masterglands.
- (b) Parathyroid and thyroid hormones regulates the amount of calcium and phosphate in extra cellular fluid. It promotes the absorption of calcium from food in intestine, it accelerates elimination of phosphates in urine.
- (a) Thyroxine's main function is to control the BMR-metabolism. These help in homeothermy in warm blooded animals.
- (c) The chromaffin cells of adrenal medulla synthesize two hormones adrenaline or epinephrine (80%) and noradrenaline or norepinephrine (20%).
- (c) Thymus is the site of differentiation of T-lymphocytes of immunity system.